Laurie Culbert

Insect Pests

OF FARM, GARDEN, AND ORCHARD

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SIXTH EDITION

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To All Entomologists Whose Studies of Insect Control Have Made the World a Better Place in Which to Live, This Book Is Sincerely Dedicated

Preface

To properly feed and clothe the expanding human populations in a world where land for agricultural production is rapidly dwindling and where demand for perfection in quality of products is high, it is essential that knowledge of destructive insects, their habits, life cycles, and latest control measures be widely disseminated. This statement, made in the fifth edition, is still appropriate for this sixth edition.

Although written primarily as a text for beginning college courses in applied or economic entomology, the book will also prove a valuable reference for more advanced or specialized courses. In addition, it should continue to serve as a convenient source of current information for research and extension entomologists, county agricultural agents, vocational agriculture teachers, and pest control operators.

When using the book in a single quarter or semester course, it is suggested that after covering the first seven chapters, a detailed study be made only of pests in a given geographical region rather than having the students master the entire book. Mastery of the entire subject of economic entomology results from continued study and research.

The same widely accepted arrangement of topics in the previous edition is followed in this one. Although the title of the book indicates that only insects are discussed, other pest problems often confronting the entomologist such as mites, snails, slugs, nematodes, and symphalids are also included.

New biological information, new references to literature, new pest species, new illustrations, new chemicals, and new approaches to insect control have been added to keep the reader abreast of the great advances that have occurred in this field of science during the past decade.

Common and scientific names, for the most part, are those approved by the Entomological Society of America.

Chemical control recommendations are less detailed in this edition. A wide variety of approved insecticides is listed for many of the major pests, but as new information becomes available changes are constantly ocurring. To keep pace with these changes the reader should periodically consult local extension entomologists who in turn should inform insecticide dealers. Such dealers have available currently recommended insecticides and the details of their use are on the labels.

To all who have given helpful suggestions or loaned new illustrations for this edition sincere appreciation is extended, particularly to B. D. Blair, R. F. Brooks, W. A. Connell, A. S. Deal, R. P. Holdsworth, Jr., G. F. Knowlton, A. E. Michelbacher, R. B. Neiswander, and Ray F. Smith.

Columbus, Ohio
August 1966

RALPH HOWARD DAVIDSON

Contents

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1

Importance of Insects to Man

One of the highly fascinating biological sciences is entomology, the study of insects. Insects are the most abundant form of animal life on the earth. They are found nearly everywhere in the world except in the open seas and some parts of the polar regions. They have been on the earth over 250 million years and seem destined to remain. Whether they are considered helpful, harmful, or neutral to man depends very largely on whether man is cooperating, competing, or indifferent to their presence.

Beneficial Effects. Insects may be helpful to man by producing, directly or indirectly, materials of economic value, such as silk, honey, beeswax, shellac, cochineal dye, cantharidin, and galls used in making tannic acid, permanent inks and dyes; by aiding in the production of fruits, vegetables, flowers, and seeds, because of pollinizing activity; by serving as food for fish, birds, and other wildlife; by destroying injurious insects either as predators or as parasites; by serving as research subjects in the study of toxicology, physiology, genetics, and related fields; by acting as scavengers, attacking and destroying dead plants and animals; by destroying noxious plants; by their medicinal value, particularly honey bee venom for treating arthritics; and by serving as objects in art, ornamentation, and in other aesthetic ways.

Harmful Effects. Insects may be harmful to man and cause great economic loss by damaging or destroying agricultural crops and other valuable plants; by aiding in the spread and development of bacteria, fungi, protozoa, helminths, rickettsia, and viruses that produce diseases and sometimes death in man and domestic animals; by aiding in the spread and development of bacteria, fungi, and viruses that produce diseases of plants; by annoying man or other animals in various ways; and by destroying or lowering the value of stored foods, other products, and possessions.

The helpful and neutral groups of insects are by far the larger since less than 1% of all insect species are considered harmful to man, but this harmful group alone causes losses averaging from 5 to 15% of the annual agricultural production. These losses have been estimated to have a monetary value of nearly 5 billion dollars each year. In addition there are the annual

expenditures for insecticides estimated to be 1 billion dollars by 1975, and for spraying and dusting equipment, over 50 million dollars. Labor costs for applying the insecticides would have to be included in the total, but no accurate figures are available.

Attempts have been made to estimate the monetary losses sustained from insect and mite attacks to crops, livestock, and man. Such estimates always result in figures of outstanding magnitude and because of the many factors involved they always vary with the authorities making them. The significance of such figures might be expressed in another way. For example, if we estimate a 10% annual loss to a corn crop because of insect attack, this means that without these pests the farmer could produce on 9 acres the same amount of corn that now requires 10 acres; that one day out of every ten he spends in the production of the crop could be used otherwise; that the equipment and land representing capital outlay could be reduced. A similar parallel could be drawn for other crops and livestock.

No matter how carefully conceived the plan for estimating insect losses, it is difficult to achieve accuracy. Further research needs to be done in this area. Nevertheless, it may be safely stated that, next to the vagaries of climate, insects and mites are one of the farmer's greatest problems the world over. People in all lines of endeavor suffer some direct loss and inconvenience and indirectly must assume their share of the losses that are felt directly by the farmer.

The need for control measures is based on many factors, and discussion of these is given in the chapters on applied control. In addition, population levels thought to be necessary before any control operation is carried out are given in the discussion of some of the problem pests.

Sources of Information in Applied Entomology. Entomologists and others concerned with studies of insect control must first have basic information. This is supplied by several standard textbooks and reference books, a few of which are included at the end of this chapter. Basic information must constantly be supplemented by progress reports on new observations and investigations in this country and abroad. Such information is commonly published in the periodicals devoted to entomology, several of which are included in the list mentioned, and in bulletins and reports issued by many agencies. The most prolific single source of such information in this country is the Entomology Research Branch, Agriculture Research Service, of the United States Department of Agriculture. Several series of publications are issued by the United States Department of Agriculture and in them are found results of research conducted in various divisions of the Service. Farmers' bulletins, technical bulletins, circulars, agriculture handbooks, yearbooks of agriculture, and variously numbered mimeographed series are some of the better known publications. The state

agricultural experiment stations, the agricultural colleges, the extension service, and endowed research institutions also issue bulletins and circulars of various kinds. Insecticide manufacturers issue much valuable information in regard to new products and discoveries. Current publications from all these sources are usually furnished free to persons in a position to make use of the information they contain. Sometimes a nominal charge is made for certain publications.

The following list includes only a few of the many books and periodicals available for those interested professionally, or as laymen, in the field of entomology. Other publications, perhaps equally valuable, are necessarily omitted. More specialized publications are listed in the appropriate chapters.

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In addition to these the student will find the following abstracting journals helpful, especially for foreign literature: *Biological Abstracts, Chemical Abstracts, Review of Applied Entomology,* and *Bibliography of Agriculture.* The insect pest surveys of Canada and the U.S.D.A. are helpful for determining distribution of insect pests.

Persons desiring additional information should get in touch with the county extension agent, the state agricultural college, or the state agricultural experiment station.

2

Structure and Metamorphosis of Insects

Recognition and control of insects are based on exact knowledge of their structure and metamorphosis.

STRUCTURE OF INSECTS

External Structure

Every insect is covered externally with a very thin nonchitinous, acid-resistant layer called the *epicuticula,* which protects the insect from excessive dryness, humidity, and disease organisms; beneath this are two noncellular but porous layers, the *exocuticula* and *endocuticula,* which contain *chitin,* a colorless polymerized glucosamine chemically related to cellulose, which resists action of ordinary corrosive chemicals; next is a continuous layer of living cells, the *epidermis* (or *hypodermis*), which secrete the substances forming the previous layers; below the epidermis is a thin layer called the *basement membrane.* All these together comprise what is known as the *exoskeleton* or body wall of an insect. The same layers of the body wall line the fore-intestine, hind-intestine, and tracheae, since these structures are ectodermal in origin.

The insect skeleton is somewhat cylindrical and made up of a series of ringlike structures called segments. These are arranged in three groups: the head, consisting of six or seven coalesced segments; the thorax, composed of three segments (*prothorax, mesothorax,* and *metathorax*) immediately following the head; and the abdomen, which numbers eleven segments in some primitive insects but is reduced in the majority of species either by fusion or telescoping of segments (Fig. 1).

Each segment is composed of several sclerotized or hardened plates, called *sclerites,* divided by juncture or union lines, called *sutures,* both named according to their location. The segments are connected by soft and flexible infolding intersegmental membranes. Some of the segments in most insects will clearly show a dorsal sclerite, called *notum, tergum,* or *tergite;*

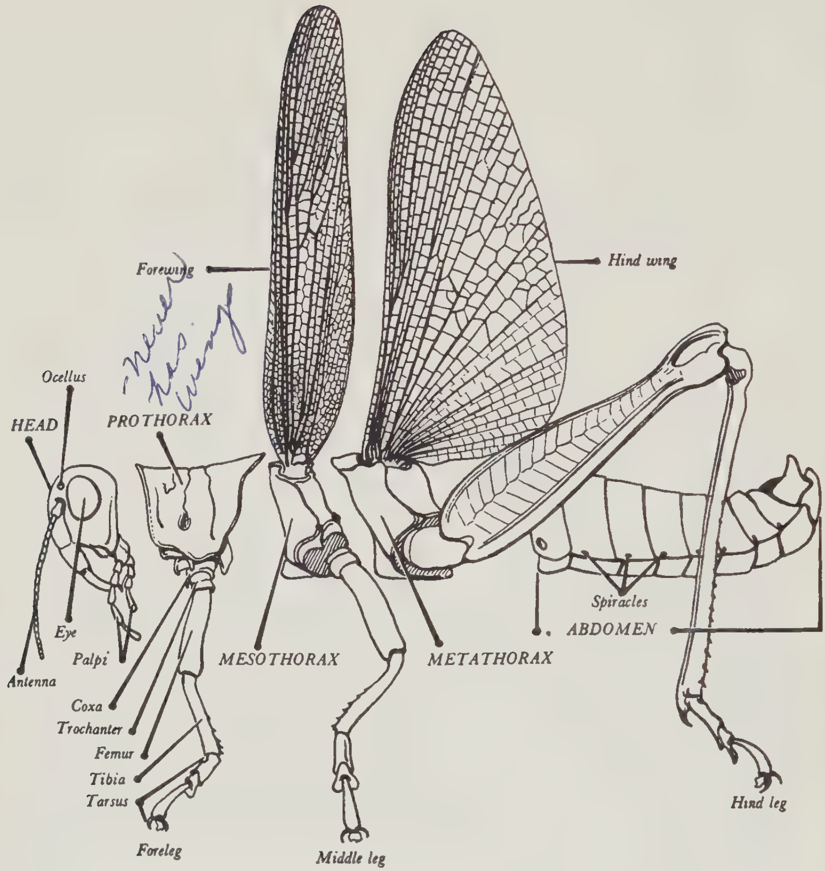

Fig. 1. The external morphology of a grasshopper. (U.S.D.A.)

lateral sclerites, known as *pleura* (singular, *pleuron*) or *pleurites;* and a ventral sclerite called the *sternum* or *sternite.* The pleural sclerites are well developed on the thorax but are reduced or lacking in the abdominal region.

Structures on the head are the eyes, antennae, and mouthparts, this region functioning primarily as a sensory center and for the intake of food.

Most adult insects have a pair of lateral compound eyes composed of a few hundred to several thousand usually hexagonal, transparent areas called *facets;* beneath each facet is a cornea and visual unit called an *ommatidium,* which detects motion and is said to produce a composite or mosaiclike image. These eyes often occupy the greater portion of the insect head. Between these compound eyes, and also in some larvae and

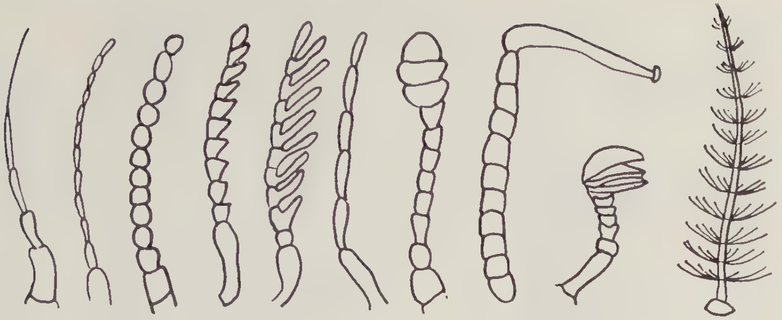

Fig. 2. Types of insect antennae: *a*, setaceous or bristlelike; *b*, filiform or threadlike; *c*, moniliform or beadlike; *d*, serrate or sawlike; *e*, pectinate or comblike; *f*, filiform or threadlike; *g*, capitate or headlike; *h*, geniculate or elbowed; *i*, lamellate or platelike; *j*, plumose or plumed. (Redrawn from various sources.)

nymphs, there are two or three light sensitive simple eyes consisting of single facets. These are called dorsal *ocelli*. Some larvae possess from one to eight lateral ocelli.

All adult insects and many immature stages have a pair of segmented antennae situated between the compound eyes or above the base of the mandibles. These are primarily sensory in function. Many modifications in form occur (Fig. 2), and these variations are of value in classification and determination of sex.

Attached to the fore or ventral part of the head are several appendages which, collectively, are called the mouthparts. These vary greatly in structure among different insects. Chewing mouthparts are considered the most primitive, a good example being those of a grasshopper (Fig. 3). Beginning anteriorly and going posteriorly the major structures are a flaplike upper lip or *labrum;* a pair of chewing jaws, called *mandibles;* a pair of *maxillae* or second pair of jaws, which bear organs of touch, smell, taste, and which also hold or cut tissues; a tonguelike ventral lobe called the *hypopharynx;* and a lower lip or *labium,* which functions in holding food and is also sensory. Each maxilla is made up of several parts; the jointed *palpus*, the *galea*, and the sharp distal structure, the *lacinia,* are the most obvious. The labium likewise is made up of several parts, the most conspicuous being a pair of segmented palpi and two distal lobes, often termed *ligula.* In insects that are adapted to feed on liquids, any of the above-named structures may be greatly modified, vestigial, or lacking. For example, the house fly can only suck up liquids; bed bugs and mosquitoes can pierce the skin and then suck blood; butterflies and moths have

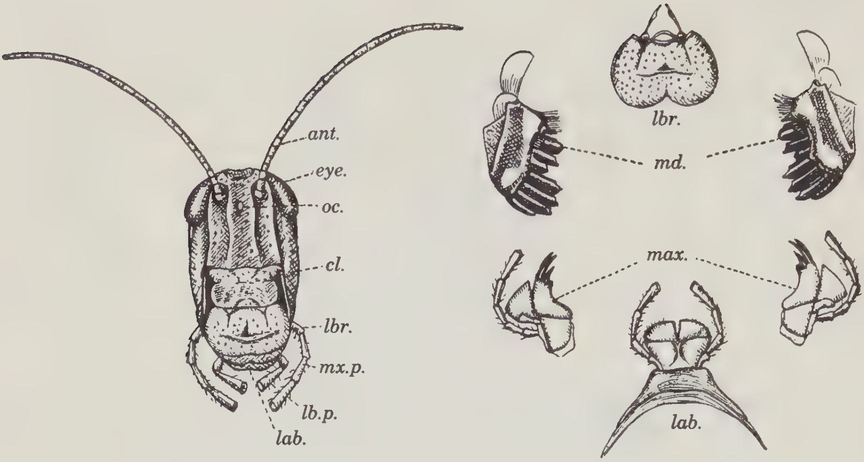

Fig. 3. Head and mouthparts of a grasshopper; (left) front view of head; (right) mouthparts dissected to show relationship and detailed structure; *ant.*, antenna; *eye*, compound eye, *oc.*, ocellus; *cl.*, clypeus; *lbr.*, labrum; *mx.p.*, maxillary palpus; *lb.p.*, labial palpus; *lab.*, labium; *md.*, mandibles; *max.*, maxillae.

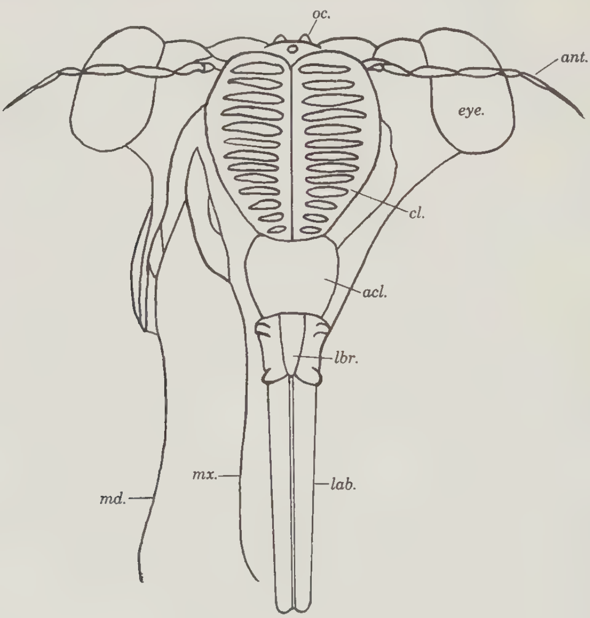

Fig. 4. Front view of a cicada head showing the main structures of a piercing-sucking type of mouthpart; *ant.*, antenna; *acl.*, anteclypeus; *cl.*, clypeus; *eye*, compound eye; *lab.*, labium; *lbr.*, labrum; *md.*, mandible; *mx.*, maxilla; *oc.*, ocellus.

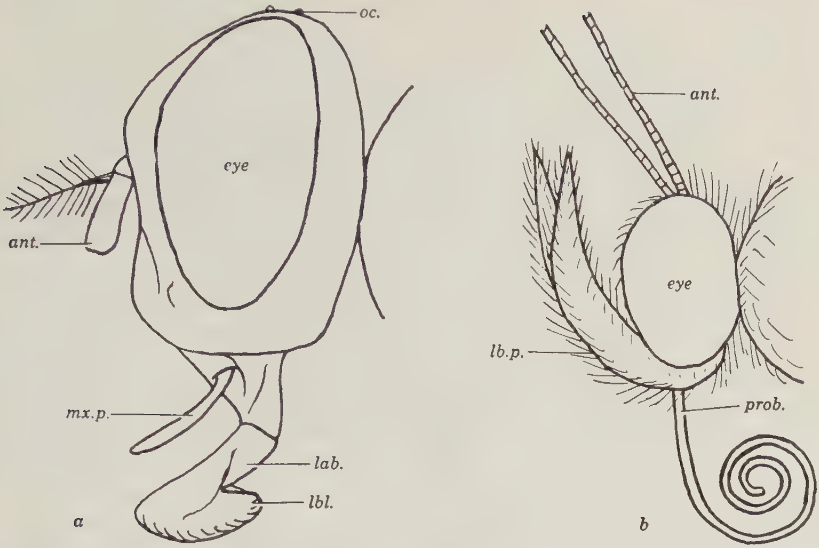

Fig. 5. Insect mouthparts: *a,* lapping or sucking mouthparts of a house fly; *b,* siphoning or sucking mouthparts of a moth; *ant.,* antenna; *oc.,* ocellus; *eye,* compound eye; *mx.p.,* maxillary palpus; *lb.p.,* labial palpus; *prob.,* proboscis; *lab.,* labium; *lbl.,* labellum.

a coiled tube-like structure which can be extended and used only in sucking up liquids (Figs. 4 and 5) but is incapable of piercing tissues; the hog louse has a piercing-sucking mouthpart, the piercing portion of which can be withdrawn into the head.

Thrips have mouthparts intermediate between the chewing and piercing-sucking types; one mandible is missing and the one present functions as a rasping structure that breaks the plant cell walls and the sap is then sucked into the mouth. This type of mouthpart is called rasping-sucking.

A major function of the thorax is locomotion. Its appendages are the legs and wings. One pair of legs is attached to each of the segments of the thorax. Each leg is divided into several parts. The basal segment is the *coxa,* which fits into a cavity known as the *coxal cavity.* The next segment is small and is called the *trochanter.* Following this is the *femur,* often the largest segment of the leg, then the *tibia,* usually as long as the femur but much more slender. Attached to the tibia is the *tarsus* (plural, *tarsi*). This is composed of one to five segments, the terminal one generally bearing one or two claws and sometimes a padlike structure, the *pulvillus* or *arolium* (Fig. 1). Insect legs vary greatly, some common categories being running, jumping, grasping, digging, or swimming types. Variations

in leg structure and tarsal segments are much used in the classification of insects.

Adult insects may be wingless or winged. If there is only one pair of wings, attachment is to the mesothorax, but if there are two pairs, attachment is to both meso- and metathorax (Fig. 1). Wings are usually membranous, often showing prominent thickened lines or veins that serve to strengthen the structure. In various groups the pattern formed by these veins is constant and frequently serves as a ready means of identification.

In many insects there are no obvious appendages on the abdomen. Some primitive forms show vestiges of legs. Others possess a pair of *cerci* at or near the tip of the abdomen. These may be very short or very long depending on the kind of insect. Several groups have in addition long segmented *anal filaments.* Females of some insects have a prominent structure that functions in the deposition of eggs. This is called an *ovipositor.* In the bees, wasps, and ants, the ovipositor is modified into a stinging organ which is retractile. The *spiracles* or external openings to the respiratory system are always present on the abdomen and one or two pairs are also found on the thorax, depending on the species of insect. Some of the major functions of the abdomen are digestion, respiration, excretion, and reproduction.

Internal Structure. The internal structures of insects are highly developed and are comparable, in their differentiation into organs and systems of organs, to the structures of the vertebrates. The functions of the organs, with certain important exceptions, closely parallel those of the vertebrates.

The insect *skeletal system* has already been discussed because it seemed logical to do so in order to properly present the information on external anatomy. It is, of course, a most obvious contrast to the vertebrate condition which is truly an endoskeleton. However, in insects, there are rigid skeletal invaginations of the body wall, called *apodemes,* which serve for muscle attachment and are usually termed the endoskeleton of the insect.

The insect *muscular system* consists of many strong, segmentally arranged, cross-striated muscles. Grasshoppers are said to have over 900 distinct muscles and some caterpillars over 4000. Although insect muscles are quite small, they are very strong, and are often capable of extremely rapid contraction.

The insect *digestive system* consists of a tube, varying in length that extends from the mouth to the anal aperture. It is often called the alimentary canal. In some insects it is almost straight (Fig. 6); in others it is quite long and convoluted. It is divided into three principal parts, the fore-intestine, mid-intestine, and hind-intestine. In some insects the fore-intestine (stomodeum) can be further divided into the *pharynx, esophagus,*

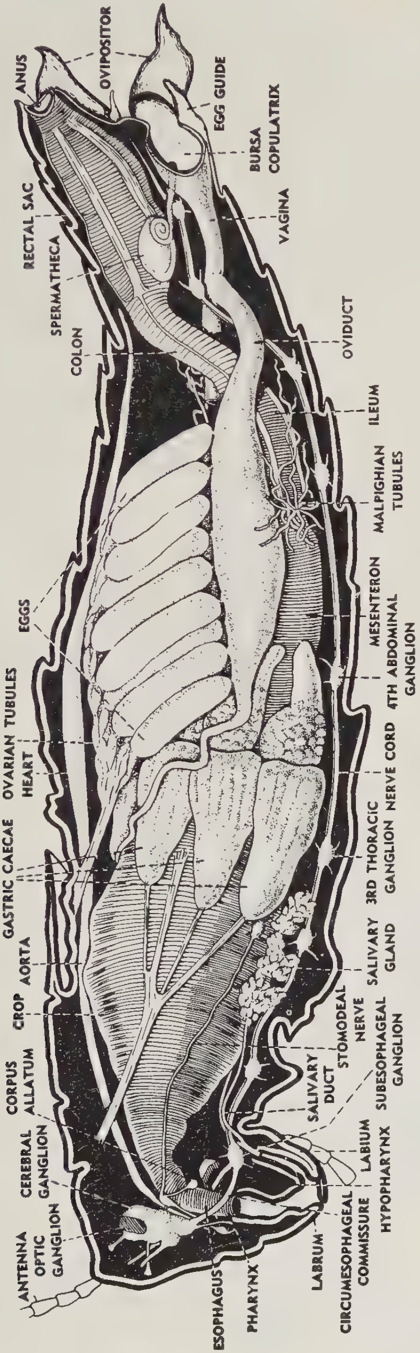

Fig. 6. A diagrammatic view of the internal organs of a grasshopper with all the major structures labelled. The *fore-intestine* extends from the mouth to the bases of the gastric caecae; the *mid-intestine* from the gastric caecae to the Malpighian tubules; the *hind-intestine* from the Malpighian tubules to the anal aperture. (Drawing by Gerberg. Reproduced through courtesy of Robert Matheson and Comstock Publishing Assoc.)

crop, and *gizzard,* and the hind-intestine (proctodeum) into the *ileum, colon,* and *rectum.* The mid-intestine is usually called the *stomach* (mesenteron) and may sometimes possess pouchlike structures called *gastric caecae.* There is generally a *cardiac valve* at the juncture of the fore- and mid-intestine, and a *pyloric valve* at the juncture of the mid- and hind-intestine. The *salivary glands* connect to the mouth near the base of the hypopharynx and are considered evaginations of the fore-intestine. Near the anterior end of the hind-intestine are attached the slender *Malpighian tubules* which function primarily in the elimination of waste products of metabolism from the blood. Their distal ends are closed and their number varies from 1 to over 150, depending on the kind of insect. The Malpighian tubules are considered to be a part of the insect *excretory system.* The entire alimentary canal functions as the site for digestion and assimilation but the mid-intestine is the principal region involved. Digestive enzymes in insects are grouped into carbohydrases, proteases, lipases, and esterases, and function in the breakdown of starches, sugars, proteins, fats, and their esters, respectively.

The *circulatory system* of the insect is an open type. It consists of a *heart,* with lateral openings or *ostia* situated in the dorsal part of the abdomen, and the *aorta* which extends forward from the heart to the head. Flow is usually anterior, the blood bathing all the organs of the body. Its function is simply to transport nutritive materials to the tissues and to carry away certain wastes. With few exceptions the blood of insects contains no red corpuscles and plays no part in respiration as does vertebrate blood. Its pH range is six to eight.

The insect *respiratory system* consists of a series of slender branching tubes, called *tracheae,* which divide and subdivide into very tiny tubes, called *tracheoles.* These ramify throughout the body and ultimately reach cell groups or individual cells where they end in minute, liquid-filled sacs, through the walls of which the respiratory exchange takes place (Fig. 7). The external openings to the tracheae are called *spiracles,* with typically two pairs located on the thorax and eight pairs on the abdomen. Movement of oxygen and carbon dioxide through the tracheal system is commonly by diffusion, but in some insects body movements undoubtedly serve to ventilate the tracheae. These movements may be called breathing. In some insects a considerable amount of respiration is by diffusion directly through the body wall.

The central *nervous system* consists of a large mass of nerve tissue in the dorsal part of the head called the *brain,* and a ladderlike series of paired segmental ganglia forming the *ventral nerve cord* which lies beneath the alimentary canal; just below the esophagus is the subesophageal ganglion composed of three fused ganglia. In the more highly specialized

insects many of the ganglia of the ventral nerve cord are fused and have shifted anteriorly. Insects also have what is termed a sympathetic nervous system, which functions in controlling the heart, digestive, respiratory, and possibly other systems, and a peripheral nervous system which functions primarily from sensory stimulation by the external environment.

The *reproductive system* of insects (Fig. 6) has essentially the same arrangement found in other animals, the females having a pair of *ovaries* and a pair of *oviducts* which unite to form a common duct leading to the *vagina,* and the males having a pair of *testes,* each attached to a seminal duct or *vas deferens* which unite to form the ejaculatory duct leading to the copulatory organ. In addition females may have a sperm storage pouch, the *spermatheca,* and a pair of *accessory glands* which secrete the material that covers egg masses or glues them to objects. The seminal vesicles of the male are enlarged or dilated portions of the vas deferens.

If greater detail on the physiology of insects is desired, consult a copy of Patton.*

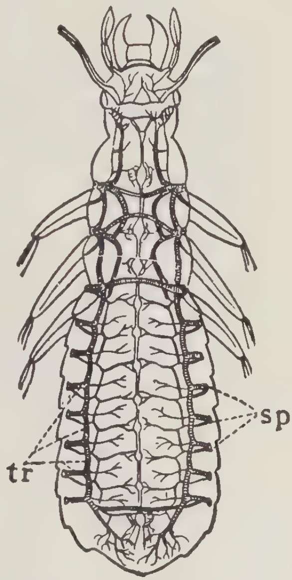

Fig. 7. The tracheal respiratory system of an insect: *tr.*, tracheae; *sp.*, spiracles; the ventral nerve cord and brain are also illustrated. (Kolbe.)

DEVELOPMENT AND METAMORPHOSIS

Most insect reproduction is sexual, an egg cell developing only after union with a sperm cell from the male. The females of many kinds of insects lay eggs and are said to be *oviparous*. Some insects also have special modes of reproduction: development from unfertilized eggs is called *parthenogenesis;* development of many embryos from a single egg is termed *polyembryony;* nourishment of the young within the female body until development is well advanced is called *viviparous* reproduction; eggs hatching within the female body, the young being born without nourishment except from the yolk, is called *ovoviviparous* reproduction. Development within the egg is embryonic and after hatching or birth it is termed postembryonic.

Eggs of insects are of the greatest variety. Some notion may be gained of the common types by observing the many illustrations of pest species

*Patton, R. L., *Introductory Insect Physiology*, W. B. Saunders Co., Philadelphia, 1963.

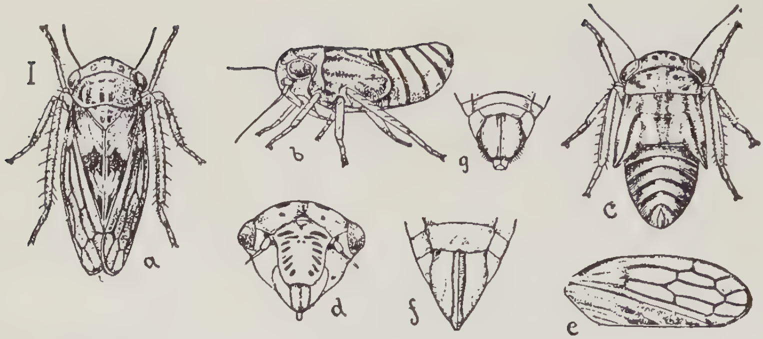

Fig. 8. Gradual metamorphosis in Homoptera: The clover leafhopper, *Aceratagallia sanguinolenta* (Prov.). *a*, adult; *b*, nymph, side view; *c*, nymph, dorsal view; *d*, face; *e*, elytron; *f*, female genitalia; *g*, male genitalia. All enlarged. Straight line (top, left) indicates actual size of insect. (Osborn and Ball, U.S.D.A.)

Fig 9. Gradual metamorphosis in Orthoptera: The German roach, *Blattella germanica* (L.). *a*, first instar; *b*, second instar; *c*, third instar; *d*, fourth instar; *e*, adult; *f*, adult female with egg case; *g*, egg case, enlarged; *h*, adult with wings spread. All natural size except g. (Riley.)

throughout the book. The number of eggs produced varies from one for some plant lice to many thousands for some social insects.

The newly hatched or born insect differs in size and often in form from the parent. The change that must take place before the young assumes the adult condition is called *metamorphosis*. The degree of change varies widely in different insects. In some it is slight and gradual; in others it is rather abrupt and complete. These variations have led to the classification of metamorphosis. If the changes are slight and gradual, if the young or *nymphs* resemble the adults, feed in the same habitat, and if wing development is external (for winged insects), the metamorphosis is described as *gradual* (Figs. 8 and 9). If the changes are very marked, the young or

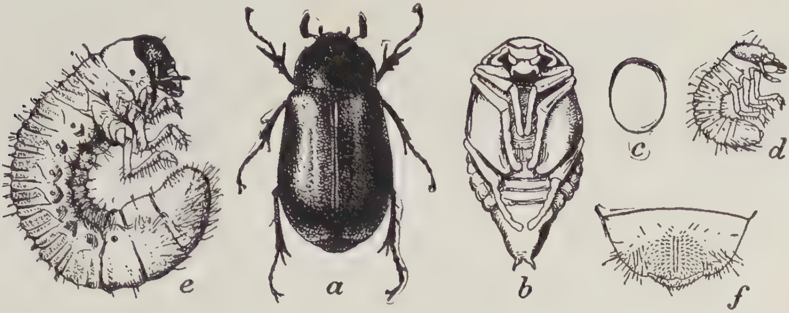

Fig. 10. Complete metamorphosis of a May beetle, *Phyllophaga fervida* (Fabr.), family Scarabaeidae: *a*, adult; *b*, pupa; *c*, egg; *d*, newly hatched larva; *e*, fully grown larva; *f*, anal segment of larva from below. All enlarged. (Chittenden, U.S.D.A.)

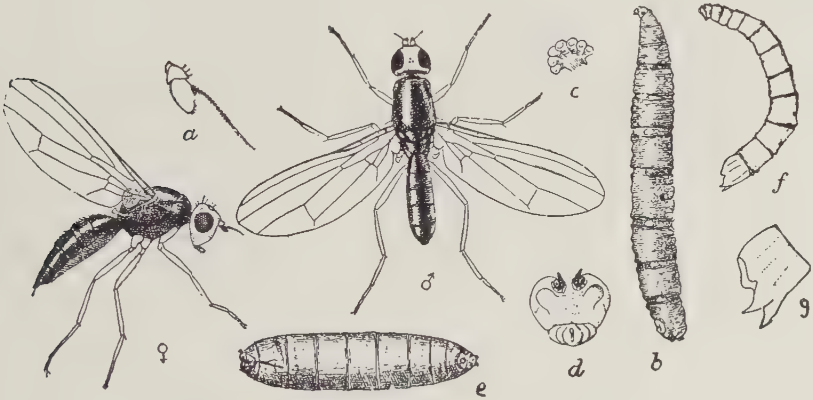

Fig. 11. Complete metamorphosis in the order Diptera. The carrot rust fly, *Psila rosae* (F.): *a*, antenna of male; *b*, fully grown larva; *c*, enlargement of larval spiracle; *d*, anal extremity of larva; *e*, puparium; *f*, young larva; *g*, enlargement of anal segment from side; male and female adults. (U.S.D.A.)

larvae not resembling the adults, the mouthparts, legs, antennae, and habitat often differing, if wing development is internal (for winged insects), and if there is an additional life stage, the *pupa*, the metamorphosis is described as *complete* (Figs. 10 and 11). In the mayflies, dragonflies, damselflies, and stoneflies, development is gradual, but the young or *naiads* are aquatic and possess gill structures which are lost when the winged adult stage is reached. This has been termed *incomplete* metamorphosis by some entomologists (Fig. 12). Others group gradual and incomplete metamorphosis together and call them both incomplete. Some entomologists

Fig. 12. Incomplete metamorphosis of a damselfly, order Odonata; adult and naiad (or nymphal) stages. (Kennedy.)

also have adopted the categories of simple and complex metamorphosis.* Regardless of the terms describing these variations, it is important for the student to have some knowledge of the complicated processes involved.

Growth begins when the sperm cell enters the micropyle of the egg. Most obvious growth is indicated by the various sizes of the developmental stages of an insect, whether it be a nymph, naiad, or larva. Since the exoskeleton cannot expand sufficiently to accommodate this increase in size, it is cast off during the process of *molting* or *ecdysis.* This process is initiated by hormones produced in the head and prothoracic regions. The brain hormone is produced by the corpus cardiacum, a paired structure situated just posterior to the subesophageal ganglia. It liberates the hormone into the blood stream, activating the prothoracic gland; this gland then secretes the hormone *ecdysone* which controls metamorphosis. In some way environmental factors stimulate the corpus cardiacum to produce the brain hormone. Closely associated with the corpus cardiacum is another paired structure, the corpus allatum, which secretes the juvenile hormone *neotinin,* which suppresses the action of ecdysone. Apparently neotinin has a balancing function in the insect endocrine system, for when the last molt is reached it is no longer secreted.

Most insects molt four times but some molt less and others molt many more. The form of an insect between successive molts is called an *instar.*

*R. E. Snodgrass applies the terms ametabolous (none), paurometabolous (gradual), hemimetabolous (incomplete), and holometabolous (complete) to describe the kinds of metamorphosis. For a detailed discussion of metamorphosis see his paper "Insect Metamorphosis," *Smithsonian Misc. Coll.,* 122 (9), 1–124, 1954.

The pupa is a nonfeeding stage during which the larval tissues are transformed into adult characters. *Chrysalid* is a term which denotes the pupa of a butterfly. Some pupae are enclosed in *cocoons* formed of silk spun from the modified salivary glands of the larvae. In many flies the pupa is enclosed in the next-to-last larval molt skin or exuvium and is known as a *puparium*.

Insect larvae are quite variable in appearance and are often classified into the following types:

campodeiform—resemble bristletails
elateriform—resemble wireworms
eruciform—caterpillars
vermiform—maggots
scarabaeiform—grubs

Pupae likewise have been categorized into the following types:

exarate—appendages free
coarctate—puparia of flies
obtect—appendages fused to body

Insects having complete metamorphosis but radically different larval instars are said to undergo hypermetamorphosis.

3

Classification of Insects

Insects comprise nearly 80% of the million or more known species in the animal kingdom. To facilitate learning about this enormous number of animals it is important that they be grouped or classified in some logical manner. The classifying can be done in various ways but the system usually followed by zoologists is based on structural characters. These include the number of cells, the type of symmetry, the number and character of the appendages, the internal and external arrangement of the body organs, and the nature of the skeletal system. On this basis the animal kingdom is divided into various categories called *phyla* (singular, *phylum*). Some of the major phyla arranged in order from the simplest to the most complex forms, with a few common examples, are as follows:

Phylum Protozoa: amoeba, paramecium.
Phylum Porifera: sponges.
Phylum Coelenterata: jellyfish, hydra.
Phylum Trochelminthes: rotifers.
Phylum Platyhelminthes: flatworms, tapeworms, flukes.
Phylum Nemathelminthes: roundworms, nematodes.
Phylum Brachiopoda: lamp shells.
Phylum Bryozoa: moss animals.
Phylum Echinodermata: starfish, sea urchins.
Phylum Mollusca: snails, slugs, oysters.
Phylum Annelida: earthworms, leeches.
Phylum Arthropoda: crayfish, spiders, mites, insects.
Phylum Chordata: fishes, amphibians, reptiles, birds, mammals.

Insects belong to the phylum Arthropoda, along with several other related forms, all of which are characterized by an external skeleton of chitin, bilateral symmetry, a segmented body, paired and segmented appendages, a ventral nerve cord, and a dorsal heart.

All animals of a given phylum are further divided, according to similarities in structure, into groups called *classes*. For example, insects constitute the class Hexapoda or Insecta, and are characterized as adults by

Fig. 13. Class Arachnida: left, a tarantula; right, a scorpion.

one pair of antennae, tracheal respiration, three pairs of true legs, and three body regions (head, thorax, and abdomen). The class Arachnida includes spiders, mites, ticks, harvestmen, scorpions, and tarantulas (Fig. 13). All these animals are characterized by two body regions (cephalothorax and abdomen), four pairs of legs (except some mites and ticks), absence of antennae, and respiration by means of tracheae, book lungs, or diffusion through the body wall. Centipedes, class Chilopoda, are elongate forms having fifteen or more pairs of legs with only one pair occurring on each body segment (Fig. 14). Millipedes, in the class Diplopoda, have elongated bodies with many legs, usually two pairs per body segment except for the first few back of the head. The class Symphyla includes tiny centipede-like animals having eleven or twelve pairs of short legs. Crayfish, sowbugs, water fleas, and lobsters, as well as many smaller forms, usually aquatic, often possessing gills, and having five or more pairs of legs, make up the class Crustacea (Fig. 15).

All the animals of each class are further divided into groups called

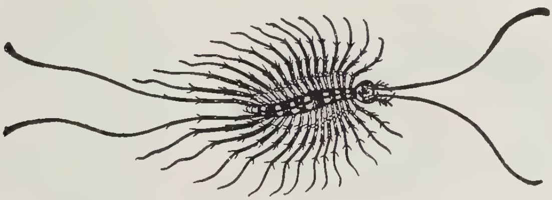

Fig. 14. Class Chilopoda: the house centipede, *Scutigera coleoptrata* (L.), a minor household pest, predatory in habit. (U.S.D.A.)

orders, and this subdivision continues, with the orders being divided into *families,* the families into *genera,* and the genera into *species.* With each division the characters for separation become more minute and more detailed, species determination frequently being based on the internal genital structures of the male.

The generic and specific names assigned a particular animal constitute its scientific name. This is followed by the name (or its abbreviation) of the person who described and named the species. For example, the scientific name of the house fly is *Musca domestica* Linnaeus. If the name of the describer following a scientific name is enclosed in parentheses, it indicates that the species has been shifted to a genus other than the one in which it was placed when described. This method of naming animals originated in 1758 with the publication of *Systema Naturae,* 10th edition, by Linnaeus, and is called the binomial system of nomenclature. At times a subspecific name is used in addition to the specific name. These are called trinomials.

The class Hexapoda is divided into orders on the basis of such characteristics as the presence or absence of wings, the wing texture, venation, number, the type of mouthparts, and the type of metamorphosis.

All entomologists do not agree as to the exact limits of an order; consequently there is a variation in the number in different publications. Of the 24 orders listed in this chapter, 17 are generally considered of minor importance and 7 of major importance. A brief summary of the differentiating characteristics will be given for all the orders, and the descriptive features of some families of economic importance in the major orders will be presented.

THE ORDERS OF INSECTS

Order Protura, the Proturans. These are tiny, elongated, wingless insects with slight metamorphosis and no eyes or antennae. The first pair of legs might be mistaken for antennae because they are carried in an elevated

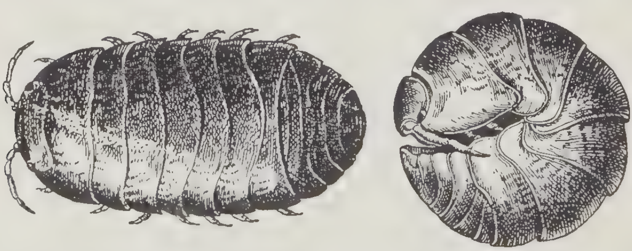

Fig. 15. Class Crustacea: sowbugs, minor pests in greenhouses; left, extended; right, rolled into a ball. (Popenoe.)

position. Proturans are found in moist habitats, principally decaying organic material. No species are considered to be pests.

Order Thysanura, the Bristletails. These are primitive, wingless, soft-bodied insects with slight metamorphosis, eyes present or absent, vestigial abdominal legs, chewing mouthparts, long, segmented antennae, definite cerci, and a long, segmented caudal filament present on some forms. Common species are about $\frac{1}{2}$ inch in body length. Firebrats and silverfish are two species of importance as pests in the household (p. 586). They are placed in the family Lepismatidae.

Order Collembola, the Springtails. These small-to-minute wingless insects have chewing-type mouthparts and slight metamorphosis. No true compound eyes are present, and many species possess a tail-like structure

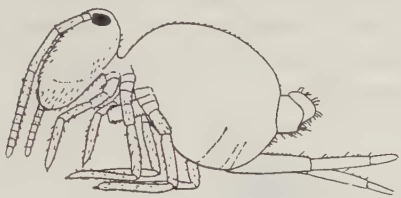

Fig. 16. A springtail; order Collembola. (Lacroix, Conn. Agr. Exp. Sta.)

that folds beneath the body and functions as an organ of locomotion (Fig. 16). Commonly found in moist or damp soil rich in organic matter, the springtails are seldom considered as major pests, but one species, *Onychiurus armatus* (Tullberg), is known to feed on seedling plants and mushrooms and a few others have similar habits. Very little is known about the life cycles of these universally distributed insects. Common families are Poduridae, Entomobryidae, and Sminthuridae.

Order Orthoptera. This group of terrestrial insects is the first of the so-called major orders; its members are variable in form and there is no common name which applies to all of them. Orthopterous insects have strong mandibulate mouthparts; their front wings are usually thickened and tend to be elongate and narrow in shape; the rear wings are membranous, broad, partly rounded in form, and folded fanlike when at rest. In the resting position the front wings cover and protect the rear wings. Some insects in this order are wingless. Sound is produced by the males of most species possessing jumping legs. Metamorphosis is gradual or simple. With very few exceptions the Orthoptera includes comparatively large insects. The number of families is small and all may be mentioned.

Family Acrididae, the Short-Horned Grasshoppers or Locusts (this family is also called **Locustidae**). Grasshoppers or locusts constitute one

of the most important groups of destructive insects in the world. They are jumping insects with antennae usually shorter than half the length of the body; the auditory organs are found on the first abdominal segment, and the tarsi are three-segmented. A discussion of the important species is given in a subsequent chapter (p. 129).

Family Tettigoniidae, the Long-Horned Grasshoppers. This family includes jumping forms with antennae as long as or longer than the body, which is always strongly arched, never flattened on top. A few species are wingless and are often mistaken for crickets, but members of this family possess four tarsal segments, whereas the true crickets have three. Katydids, meadow grasshoppers, cave and Mormon "crickets" are typical members of this group. Cave "crickets" sometimes are troublesome in greenhouses, and Mormon "crickets" are at times very destructive to crops in Utah and nearby states (p. 134). Except for the latter insect the economic importance of this family is not great.

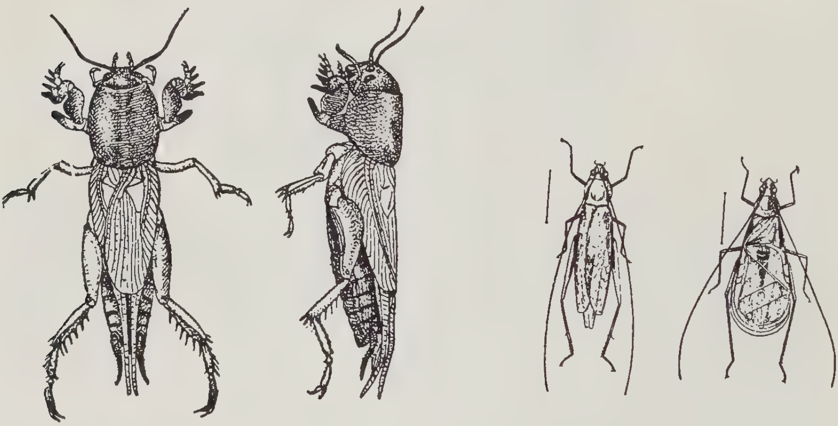

Fig. 17. The northern mole cricket, *Gryllotalpa hexadactyla* Perty (U.S.D.A.), and the black-horned tree cricket, *Oecanthus nigricornis* Walker, family Gryllidae. (Summers.)

Family Gryllidae, the Crickets. Crickets are jumping insects with rather heavy bodies. The tarsi are three-segmented and the ovipositor spear-shaped. Common species represented are field, house, mole, and tree crickets (Fig. 17). Occasionally some of these species are quite destructive to crops.

Family Phasmidae, the Walkingsticks. The American species are large, commonly 3 to 6 inches in length, nearly all wingless, very narrow and elongate, with long slender legs. Walkingsticks devour the foliage of trees, usually oak, and occasionally cause serious damage. The females oviposit

while in the trees, the eggs dropping to the ground. One generation develops each year and eggs are the overwintering stage.

Family Mantidae, the Praying-Mantids. A mantid is a very striking insect of elongate form with the front legs modified into prominent grasping organs which catch and hold the prey of this beneficial predatory insect. Both native and introduced species are quite large, some over 4 inches in length. Winter is passed as masses of eggs glued to twigs or other objects. One generation develops each season.

Family Blattidae, the Cockroaches. These are broad, oval, much flattened insects with well-developed running legs. Several species are dwelling pests (Fig. 528); others occur outdoors in rotting logs and stumps. Nearly 70 species are found in North America and over 2000 are known in the world. The species that are troublesome to man are discussed under household insects (p. 584).

Order Isoptera, the Termites. This group of small chewing insects includes many species in the world, but in North America the most destruc-

Fig. 18. The common termite; order Isoptera. (McDaniel, Mich. Agr. Exp. Sta.)

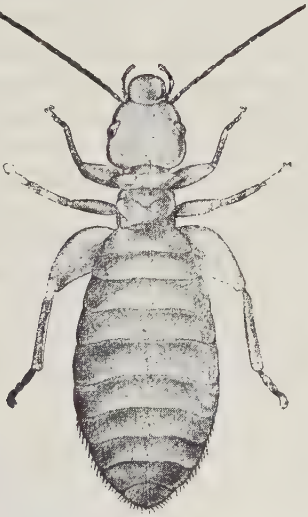

Fig. 19. The common booklouse, *Liposcelis divinatorius* (Müller); order Psocoptera. (Back, U.S.D.A.)

tive forms are called subterranean termites (Fig. 18). They live together in colonies under a caste system which includes workers, soldiers, supplementary reproductives, a king and a queen. Wingless and winged individuals develop, the winged forms possessing two pairs of equal size and

of membranous texture. Metamorphosis is usually described as gradual. A detailed description of the subterranean species is given under household insects (p. 579). Families represented in the United States are Rhinotermitidae and Kalotermitidae.

Order Psocoptera, Psocids and Booklice. These are small-to-minute insects with chewing mouthparts and gradual metamorphosis. Both winged and wingless forms occur. Winged forms have two pairs of membranous wings with simple venation, the second pair usually much shorter. They often are found on the bark of trees and are sometimes known as bark-lice (family Psocidae). The wingless forms, booklice (family Liposcelidae), are numerous at times and may become pests in libraries and homes. They are minute, brown, with relatively long legs and antennae (Fig. 19). They feed on glue, paste, dried insects, fungi, grain, and many milled food products as well as other organic substances. Booklice are easily controlled by residual sprays of DDT, chlordane, or methoxychlor.

Order Dermaptera, the Earwigs. These are elongate, slender insects, some reaching a length of over half an inch. They have chewing mouthparts, gradual metamorphosis, and a pair of pincerlike cerci. When winged, the front pair are thickened and very short, and the hind pair are membranous and much folded. They closely resemble the rove beetles. A few species are minor pests of garden crops, and one, the European earwig (Fig. 20), sometimes becomes a nuisance in houses. Only a half dozen species are common in this country. The common family is Forficulidae.

Order Thysanoptera, the Thrips. Small-to-minute, slender insects constitute this order. Both wingless and winged individuals are found, the latter having four very narrow wings fringed with long hairs (Fig. 21). Metamorphosis is gradual but an incipient pupal stage is indicated. The mouthparts are classified as rasping-sucking. The order includes many de-

Fig. 20. The European earwig, *Forficula auricularia* L.; left, males; right, females; order Dermaptera. (U.S.D.A.)

Fig. 21. The flower thrips, *Frankliniella tritici* (Fitch). (Fla. Agr. Exp. Sta.)

structive plant species that may occur in vast numbers. A more detailed description of these may be found elsewhere in this book (pp. 234, 312). Species of economic importance are in the family Thripidae.

Order Mallophaga, the Chewing Lice. Small, flattened, wingless insects, with gradual metamorphosis and chewing mouthparts, make up this order of ectoparasites of birds and mammals. Most species attack birds and domesticated fowls; none are known to attack man. All life stages are spent on the host and spread is by contact. A detailed discussion of the important species in this order including illustrations is given in Chapter 23.

Order Anoplura, the Sucking Lice. This group includes all the blood-sucking lice ectoparasitic on mammals. They are small, wingless, flattened insects with gradual metamorphosis and piercing-sucking mouthparts. They also have more pointed and elongate heads than the biting lice. These insects are irritating and annoying, greatly lowering the vitality of livestock. Species attacking man are vectors of some dreaded diseases. A detailed discussion of the important species along with illustrations is given in Chapter 23.

Order Hemiptera, the True Bugs. Insects of this order may be wingless; when wings are present the first pair is usually thickened and leathery at the base and membranous at the tips, and the second pair is entirely membranous. At rest, the wings cover the abdomen with the membranous tips of the first pair overlapping. The mouthparts are piercing-sucking and metamorphosis is gradual. There are many families of true bugs but only a few of considerable importance will be named.

Family Cimicidae, the Bed Bugs. A description of the one common

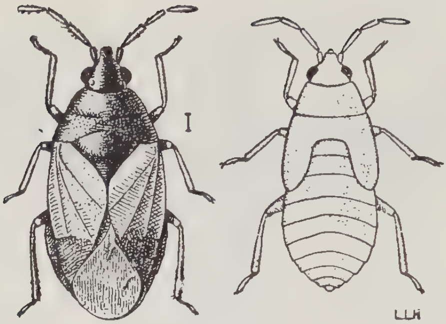

Fig. 22. Adult and nymph of *Orius insidiosus* (Say), a small predaceous bug that attacks mites and small insects; family Anthocoridae. (Ewing, Ore. Agr. Exp. Sta.)

species of these wingless, blood-sucking ectoparasites of man and other animals is sufficient for the entire family (see Chapter 23).

Family Miridae, the Leaf or Plant Bugs. This group of rather small bugs includes a number of very destructive pests of agricultural crops. The antennae and proboscis are four-segmented, and the membrane of the fore wing usually has two closed cells at its base. Important species are discussed and illustrated in succeeding chapters of this book.

Family Anthocoridae, the Flower or Minute Pirate Bugs. This family of tiny bugs includes the important species, *Orius insidiosus* (Say) (Fig. 22). All species attack and destroy mites, scales, aphids, leafhoppers, and the eggs of these pests.

Family Phymatidae, the Ambush Bugs. This family is important because it includes predatory species that are recognized by their greatly thickened front legs.

Family Reduviidae, the Assassin Bugs. Medium-to-large predatory bugs belong to this family, some reaching almost 2 inches in length. They have four-segmented antennae, no ocelli, and a three-segmented beak which fits into a prosternal groove. Several species are valuable predators and a few are likely to attack man but these are classed as being of minor importance.

Family Nabidae, the Damsel Bugs. This is a group of bugs mentioned only because it includes important predaceous species that destroy great numbers of destructive insects each year (Fig. 23).

Family Tingidae, the Lace Bugs. All the members of this family are small with many wing veins, giving a lacelike appearance to the insect (Fig. 24). Some species have expanded lobed areas that extend over the head. The beak and antennae are four-segmented, the tarsi are two-seg-

Fig. 23. *Geocoris decoratus* Uhler, family Lygaeidae (left), and *Nabis alternatus* Parshley, family Nabidae (right); both predaceous insects. (Knowlton, Utah Agr. Exp. Sta.)

mented, and ocelli are absent. Several species are important pests of trees, shrubs, and vegetable crops.

Family Lygaeidae, the Lygaeids. Lygaeids have four-segmented beaks and antennae but only five or six veins in the wing membrane. They vary considerably in size, some being quite small, others nearly three-fourths inch in length. The chinch bug is considered the most injurious species in the family (see p. 178). All are plant-feeding species except those in the genus *Geocorus,* which are predaceous on other insects (Fig. 23).

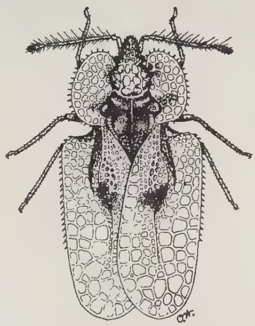

Fig. 24. Adult sycamore lace bug, greatly enlarged; family Tingidae. (Wade.)

Family Coreidae, the Coreids. Coreids are often large bugs, but there are some small species. They are elongate and robust in form; their beaks and antennae are four-segmented, and the membranous portion of the front wings has many veins. Both plant-feeding and predaceous species are found. The squash bug is the best known of the pests belonging to this family, but there are other destructive species.

Family Pentatomidae, the Stink Bugs. This group includes a number of rather large, broad, shield-shaped bugs, with five-segmented antennae and a prominent scutellum (Fig. 25). Many

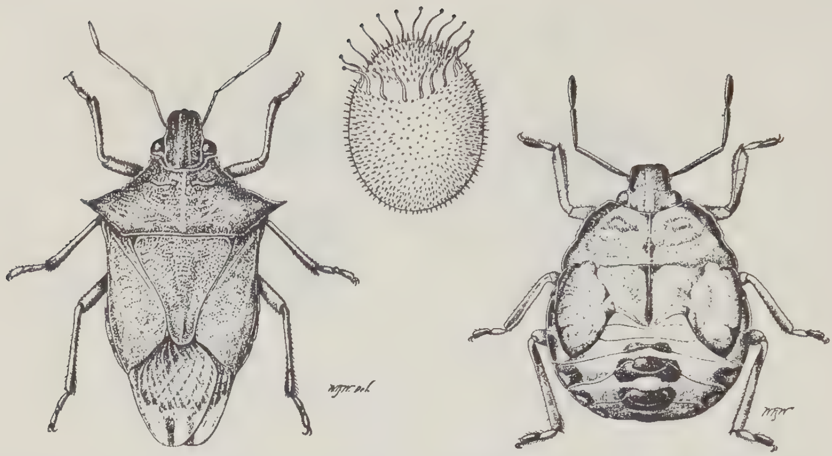

Fig. 25. The spined soldier bug, *Podisus maculiventris* (Say), family Pentatomidae. From left to right: adult, egg, nymph. (Walton, U.S.D.A.)

species are predatory and beneficial; several others are important plant pests. This family includes most of the bugs possessing stink glands.

In addition to the previously named families, the order includes several groups of common aquatic insects, many of which are predaceous, as well as a number of small families of terrestrial species, most of which are not sufficiently destructive to attract notice.

Order Homoptera. There is no one common name generally acceptable to indicate all members of this order, which is sometimes considered a suborder of Hemiptera. Homopterous insects have piercing-sucking mouthparts similar in structure to those of the true bugs but attached at the base of the head, often appearing to arise from the thorax between the coxae. Wingless and winged individuals are found. Those with wings commonly have two pairs, both membranous; some families are characterized by forms with the front pair slightly thickened. Male scale insects only have one pair of wings. Metamorphosis varies from gradual to a form which approaches completeness. Members of this order feed only on plant juices, and many of them are quite injurious. Size, with few exceptions, is medium to small or even minute. The number of families is not great, and the most common ones are characterized briefly in this summary. Detailed information about many species in this order is given in subsequent chapters.

Family Cicadidae, the Cicadas. Cicadas are often mistakenly called locusts. They are large insects, the common species being 1.5 to 2.5 inches in length, far exceeding all other members of the order (in the United

States) in size. The so-called 17-year locust or periodical cicada is a destructive species; the common dog-day harvestflies or annual cicadas are of lesser importance (see p. 389).

Family Membracidae, the Treehoppers. This family includes medium to rather small insects with the pronotum or top of the prothorax greatly enlarged. The pronotum usually covers the head from above and projects backward, often hiding much of the wings and abdomen (Fig. 26). It may be strongly angulate with the angles sometimes produced into hornlike processes. Treehoppers feed on trees, shrubs, and legumes, and do further damage by their habit of ovipositing in woody plants (see p. 391).

Fig. 26. Nymphs and adults of *Stictocephala* sp., a treehopper, family Membracidae. (Yothers, U.S.D.A.)

Fig. 27. A planthopper, *Ormenis* sp., family Fulgoridae. A minor pest of grape. (U.S.D.A.)

Family Fulgoridae, the Planthoppers. This family includes a wide variety of forms, which can be distinguished from spittlebugs and leafhoppers by the antennae that are attached to the head below the compound eyes. The antennae are thickened at their base and terminate in a bristle-like process. Members of this group have rarely attracted attention by their feeding habits, but many of them are rather conspicuous and interesting insects (Fig. 27).

Family Cercopidae, the Spittlebugs. These insects resemble robust leafhoppers but can be distinguished from them by the circlet of spines at the

base of the hind tibiae. The hind tibiae also bear a few heavy spurs, whereas a double row of spines is found on leafhoppers. The nymphal instars develop only inside foamy spittle masses which are easily detected on the host plants. Any perennial plant may be damaged, but legumes, strawberries, and many nursery crops are often seriously injured. The common species is discussed in detail under the section dealing with insects attacking legumes (Chapter 11).

Family Cicadellidae, the Leafhoppers. Leafhoppers are among the most abundant of insects. Many species are to be found in any locality. A few are of medium size up to ½ inch in length, but most of the destructive species are quite small (Fig. 28). They are usually slender and elongate,

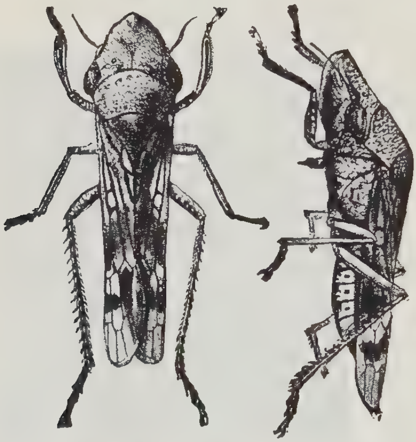

Fig. 28. Dorsal and side views of the cotton sharpshooter or leafhopper, *Homalodisca coagulata* (Say), family Cicadellidae. (Riley and Howard, *Insect Life*.)

Fig. 29. The bean aphid, *Aphis fabae* Scop., family Aphididae. (U.S.D.A.)

with rounded or pointed heads and a double row of spines extending the entire length of the hind tibiae. A considerable number of important species will be discussed in following chapters.

Family Aphididae, the Aphids or Plant-Lice. Aphids are small, sluggish, soft-bodied insects, usually green, but sometimes brown, red, black, or purple, and winged or wingless, which feed in groups on any part of the host (Fig. 29). In most species a pair of dorsal abdominal projections near the posterior part of the body, called *cornicles*, are of value in identification, as are the antennal characters. Since there are many illustrations throughout this book, detailed description here is unnecessary. Aphids are among the

most important plant pests and few crops are free from attack by one or more species.

Family Phylloxeridae, the Phylloxerans. This group of insects resembles aphids in appearance and in complexity of the life cycle. The best example of a pest species of this family is grape phylloxera (p. 497).

Family Psyllidae, the Jumping Plant-Lice or Psyllids. Members of this family resemble tiny cicadas or winged aphids. The adults are more active than aphids, having hind legs fitted for jumping. Many species attack woody plants, which they injure in a variety of ways, but only a few species are classed as important crop pests, among them the pear psylla and potato psyllid.

Family Aleyrodidae, the Whiteflies. Whiteflies are minute insects with broad wings which are covered with fine, snow-white, waxy powder. In the North only a species found in greenhouses is injurious although a few others occur. In the South several species are seriously injurious to citrus and other plants. The immature stages resemble those of scale insects. Illustrations and further discussion are given in Chapters 13 and 21.

Family Diaspididae, the Armored Scales. In this family the soft body of the insect can be removed from the hardened scale covering which is composed of two exuviae and a waxy secretion. Except in the first instar, scale insects have little or no resemblance to insects. They commonly appear as excrescences on the plants on which they feed. There are numerous species, many of which attack woody plants (Fig. 30) (see Chapters 16 and 21).

Family Coccidae, the Soft or Unarmored Scales. In this group of scales,

Fig. 30. Pine needle scale, family Diaspididae (*left*) (Neiswander, Ohio Agr. Exp. Sta.); the citrus mealybug, family Pseudococcidae (*right*).

the waxy covering over the insect is actually the body wall and it cannot be separated from the insect itself. Some species are large and rounded, others broad and flattened, but all species are not as hard as the armored scales. Soft scales, often excreting copious quantities of honeydew, are associated with ants. Pest species are covered in detail in Chapters 16 and 21.

Family Pseudococcidae, the Mealybugs. These are oval sluggish insects with short spines on the body margin and a covering of mealy white powder (Fig. 30). As the period of egg-laying approaches for oviparous species, they are often buried in a mass of cottony fiber. A great many species occur both inside and outside greenhouses. Important ones are discussed in detail in Chapter 21.

Order Ephemeroptera, the Mayflies. Adults are delicate slender insects, varying from small to rather large in size. They have four membranous wings with many veins, the front pair being much larger than the hind pair. In some genera the hind wings are vestigial. The antennae are inconspicuous, the compound eyes large, the mouthparts vestigial; the abdomen has a pair of long segmented cerci and often a long median caudal filament. Metamorphosis is incomplete, the aquatic nymphs or naiads have chewing mouthparts and little resemblance to the adults. Members of the order are often extremely numerous in the vicinity of streams and lakes. Except for the fact that they are a source of food for fishes, mayflies are of no consequence to man. Common families are Ephemeridae, Heptageniidae, and Baetidae.

Order Plecoptera, the Stoneflies. Stoneflies vary in color, form, and size, some reaching a length of 2.5 inches. They have chewing mouthparts, long filiform antennae, a pair of cerci, and two pairs of membranous many-veined wings, the front ones narrow and elongate, the hind ones broad and folded fanlike under the front wings when the insect is not in flight. Metamorphosis is considered incomplete, the nymphs or naiads being aquatic and generally found in streams clinging to stones. In the immature stages they undoubtedly serve as food for other aquatic insects and fishes. Perlidae is the largest family of stoneflies.

Order Odonata, the Dragonflies and Damselflies. These are medium-to-large insects, some reaching a wingspread of over 4 inches. They have chewing mouthparts, bristlelike antennae, long slender bodies, and four long, narrow, net-veined wings of equal or subequal size. Metamorphosis is incomplete, the nymphs or naiads being aquatic and bearing little resemblance to the adults. Dragonflies are noted for their strong, graceful flight; damselflies have similar characteristics but are much smaller and more delicate creatures. Both nymphs and adults are predatory in habit, the nymphs devouring mosquito larvae and other aquatic life, the adults

catching various insects on the wing. The predatory habits of the adults are not considered of great value in the control of pest species. Members of this order are probably better known than most of the other minor groups because of their large size and their diurnal activity. Common families are Aeschnidae, Gomphidae, Corduliidae, Libellulidae, Agrionidae, Coenagrionidae, and Lestidae.

Order Neuroptera, the Nerve-Winged Insects. Neuropterans are usually medium-to-large insects, but several very small species occur in the order. They have four elongate, membranous wings of nearly equal size with numerous longitudinal veins and many cross veins. Bodies are slender, the antennae prominent, the mouthparts chewing, and the metamorphosis complete. The larval stages are predatory, and some species are valuable aids to man in the natural control of small insects. The aphid lions or lacewings (family Chrysopidae) are important as predators of insects such as plant-lice, scales, and thrips (Fig. 31). "Doodlebugs" are larvae of the ant lions (family Myrmeleontidae) which are predaceous on ants. The mantispids (family Mantispidae) (Fig. 32) resemble praying-mantids, the larvae attacking spider egg sacs and the nests of certain wasps.

Order Megaloptera, the Dobsonflies and Fishflies. The members of this order are sometimes classified with the Neuroptera, but they can be readily treated as a separate order. They are variable in size, some of the dobsonflies being more than 4 inches in length. Their two pairs of wings are nearly equal in size and coarsely net-veined, the mouthparts chewing,

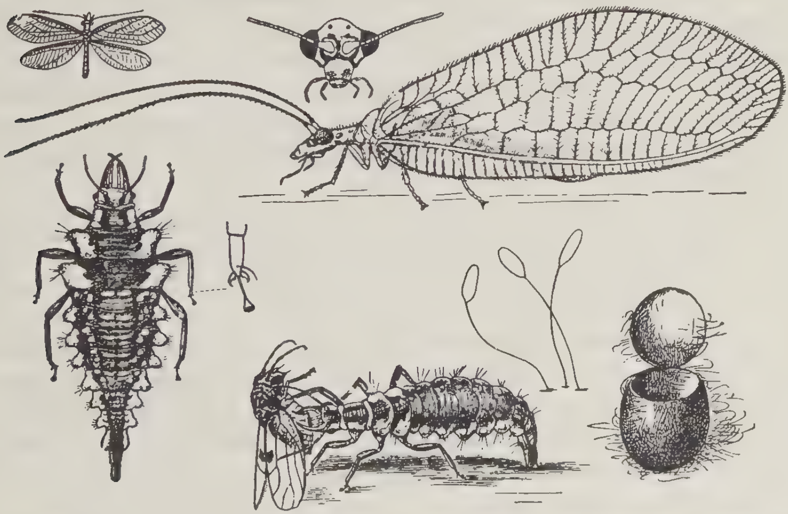

Fig. 31. Complete metamorphosis in Neuroptera. Eggs, larvae, cocoon, and adults of a lacewing. (U.S.D.A.)

Fig. 32. A mantispid, *Mantispa* sp., parasitic within egg masses of spiders. Order Neuroptera.

the metamorphosis complete, and the larvae aquatic. The best-known form in the order is the hellgrammite, or larva of the dobsonfly. These larvae are predaceous on other aquatic insects and serve as food for fishes or as fish bait. The alderflies are placed in the family Sialidae, and the dobsonflies and fishflies in the family Corydalidae.

Order Mecoptera, the Scorpionflies. The common species in this order are slender-bodied, nearly 1 inch or more in length, with two pairs of narrow elongate wings of almost equal size, and having a relatively small number of veins. The legs are long—the insects resemble crane flies. The chewing mouthparts of these predatory insects occur at the tip of a downward prolongation of the head. Metamorphosis is complete but the larvae are rarely encountered. There are some very small species that are apterous. No economic importance is ascribed to the scorpionflies. The common name of these insects is derived from the scorpionlike resemblance of the recurved tip of the abdomen, which is evident in males of the family Panorpidae. The hanging scorpionflies are members of the family Bittacidae.

Order Trichoptera, the Caddisflies. These insects resemble moths, having four wings sometimes with scales but always with numerous hairs. When not in flight the wings are held rooflike over the body. A few species are apterous. The adults are variable in size, some being quite small, others reaching 1.5 inches in length. Adults have chewing or vestigial mouthparts, and the larvae have well-developed chewing mouthparts. Metamorphosis is complete, the aquatic larvae constructing silken cocoons or cases, often of very interesting form, found attached to rocks or floating free in the water. Caddisflies are said to constitute the largest group of predominantly aquatic insects.

Order Lepidoptera, the Moths, Skippers, and Butterflies. Adults in this order are usually recognized by the dense covering of tiny scales and

hairs on their wings and bodies, but there are a few species with wings devoid of scales. Their mouthparts consist of a long flexible tube formed for sucking or siphoning, the palpi are often prominent, the antennae are of various types, and the two pairs of wings are membranous. Some wingless females occur in a few species. Metamorphosis is complete, and the chewing larvae are called caterpillars. These are elongate, cylindrical, wormlike creatures with three pairs of thoracic legs and fleshy abdominal prolegs. There are normally five pairs of prolegs, but in the looping species this number is reduced. Many caterpillars spin elaborate silken cocoons in which pupation occurs. Commercial silk comes from the salivary glands of the silkworm.

The order is a large one, the great majority of the species being moths. Since most of these are phytophagous, it is not surprising that a great number of injurious species are to be found among them. Butterflies and skippers are relatively unimportant. They are diurnal and comprise only a few of the many families in the order. Only the more conspicuous and important families will be mentioned.

Family Papilionidae, the Swallowtail Butterflies. Large butterflies, many with tail-like projections on the hind wings, are too well known to require further description. A pest species is the celery butterfly.

Family Pieridae, the White and Yellow Butterflies. There are many species in this family and the coloration is predominantly white, yellow, and orange, or combinations of these with some black spotting. The imported cabbage butterfly and the alfalfa butterfly are two of the common destructive species; otherwise the members of the family are innocuous.

Family Lycaenidae, the Gossamer-Winged Butterflies. These are usually very small butterflies, frequently colored blue, slaty, brown, or copper, the latter forms having a metallic sheen. They are of very little importance as pests.

Family Nymphalidae, the Four-Footed Butterflies. This is the largest family of butterflies, but some taxonomists have been dividing it into several others. Nymphalids vary from small to quite large forms with a great variety of color combinations. They are usually recognized by the reduced size of the front legs and they walk only on the hind two pairs. Only a few pests occur in the family and they are of minor importance.

Family Hesperiidae, the Skippers. Skippers are dark or tawny yellow and brown, of medium-to-small size, usually with recurved or hooked antennae. Their larvae are peculiar in that they have a necklike constriction just back of the head. The diurnal skippers make short flights, hence the common name. A few species sometimes become destructive to crops in this country.

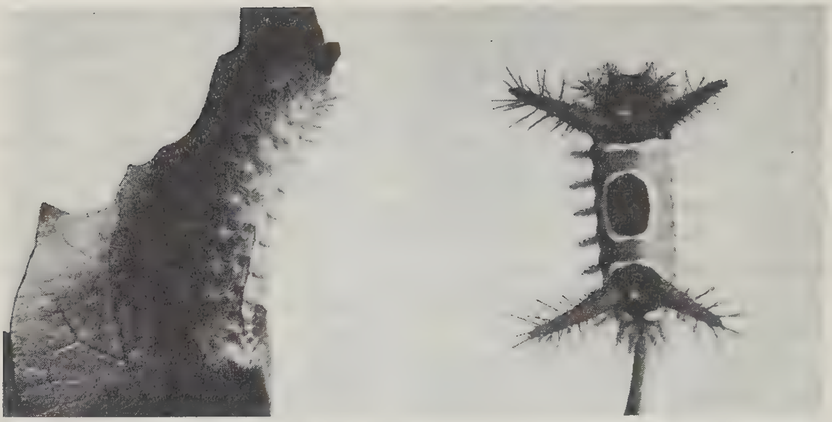

Fig. 33. (Left) *Automeris io* (F.), family Saturniidae, and (right) *Sibine stimulea* (Clem.), the saddle-back caterpillar, family Limacodidae. Both have nettling hairs, annoying to man. (U.S.D.A.)

Family Saturniidae, the Giant Silkworm Moths. The largest of our moths belong to this family, some having a wingspread of 10 or more inches. Both adults and larvae attract attention because of their bright coloration and large size. The larvae feed on the foliage of trees and shrubs, but this is not considered important because of their small numbers. Some of the better-known species are the *cecropia, luna, polyphemus, promethea,* and *io* (Fig. 33) moths.

Family Citheroniidae, the Royal Moths. This family includes two very large species and several smaller ones. Possibly the best-known form is the larva of the regal moth which is called the hickory horned devil. This harmless caterpillar reaches a length of 5 or more inches and has several prominent curved hornlike processes on the thoracic segments, giving it a ferocious appearance. The other large species is the imperial moth, the larva of which feeds on foliage of trees and shrubs. Neither species is important as a pest.

Family Sphingidae, the Sphinx or Hawk Moths. Hawk moths vary considerably in size and coloration, some having a wingspread of less than 2 inches, others of over 6 inches. They are heavy-bodied with large narrowed fore wings and much smaller rounded hind wings (Fig. 34). They usually fly at dusk and are able to hover in the air over flowers from which they suck nectar. Large species are often mistaken for humming-birds. The larvae are called hornworms, and several species are important defoliators of tobacco, tomato, grape, and catalpa.

Family Noctuidae, the Noctuids. This family includes about a third of all species of moths. Although many are medium-sized, having a

Fig. 34. (Left) the tomato hornworm, *Manduca quinquemaculata* (Haworth), family Sphingidae, and, (right) a heavily parasitized larva. Note the long sucking mouthpart in extended position. (Lacroix, Conn. Agr. Exp. Sta.)

wingspread of 2 inches or less, some reach a wingspread of nearly 4 inches. Dull brown-to-black with gray mottling is the prevailing coloration, but the second pair of wings is colorful in some species. Many of our serious crop pests are in this family, cutworms, armyworms, bollworms, fruitworms, corn earworm, and cabbage looper (Fig. 35) being common examples. Discussions of these, along with illustrations, will be given in later chapters.

Family Arctiidae, the Tiger Moths. Arctiids may have a wingspread of 2 inches or less. They are often brightly colored, but several are entirely white. Others have black and orange patterns, suggesting the common name of the family. Larvae are hairy, many of our common "woolly worms" or "woolly bears" belonging to this group. Although a few species are pests, none is of great importance.

Family Geometridae, the Measuring Worms. Adults of this family are medium-to-small moths, often delicate in appearance (Fig. 36). Larvae are rather easily recognized by their looping or measuring method of crawling (Fig. 37). A few species will sometimes completely destroy the foliage of woody plants.

Family Liparidae, the Tussock Moths. This is not an extensive group, but a few of its members are very destructive. The gypsy, brown-tail, and white-marked tussock moths are typical important species that are discussed in detail in Chapter 16.

Family Notodontidae, the Prominents. This group closely resembles the noctuids. Probably the best species to exemplify the family are the yellow-necked, walnut, and red-humped caterpillars which feed on the foliage of woody plants. They are included in discussions in Chapter 16.

Fig. 35. Complete metamorphosis in Lepidoptera. The cabbage looper, a noctuid. The larva is of the semi-looper type. *a*, male moth; *b*, egg from above and from side; *c*, full-grown larva in natural feeding position; *d*, pupa in cocoon. (U.S.D.A.)

Fig. 36. The currant spanworm, *Itame ribearia* (Fitch), family Geometridae: *a*, egg (greatly enlarged), *b*, eggs on twig, adult (left), larvae and pupa (right). (Saunders.)

Fig. 37. Typical measuring worms: the chain-spotted geometer, *Cingilia catenaria* (Drury), family Geometridae. (Quaintance, U.S.D.A.)

Fig. 38. The fruit-tree leaf roller, *Archips argyrospilus* (Walker), family Tortricidae, showing the egg mass, larva, pupa, and adult. (Childs, Ore. Agr. Exp. Sta.)

Family Lasiocampidae, the Tent Caterpillars. The important members of this family devour the foliage of trees. They are given special consideration in a later discussion (see p. 397).

Family Bombycidae, the Silkworm Moths. This family contains the species, *Bombyx mori* (Linnaeus), the true silkworm of Asia. It is reared artificially on mulberry leaves for the purpose of producing silk commercially. Culturing these caterpillars is still done in a number of countries, and the silk produced is said to have a commercial value of $200 to $500 million annually.

Family Tineidae, the Tineids. Some very small buff moths occur in this family. Common species known to most people are the clothes moths (p. 587).

Family Tortricidae, the Leaf Rollers. These are small moths, the larvae of which roll or fold the leaves of plants, tying them with silk and feeding on the inside. Several important species (Fig. 38) are discussed in the book.

Family Olethreutidae, the Olethreutid Moths. Members of this family

are rather small and drab in appearance. Some of the very important pest species are the codling moth, oriental fruit moth, and grape berry moth. These species are discussed thoroughly in the appropriate chapters. Over 700 species in this large family of moths occur in the United States.

Family Aegeriidae, the Clear-Winged Moths. All species in this family have much of the membranous wing area devoid of scales. Their wings are narrow and their bodies slender. Many adults resemble wasps and are diurnal in habit. The larvae are borers, usually in woody plants where damage is often quite serious. The peach tree borers and the squash vine borer are examples of destructive species.

Family Psychidae, the Bagworm Moths. The larvae of members of this family construct large cases about themselves in which they feed on the foliage of trees and shrubs. The adult male has wings with very few scales; the female is wingless (see p. 393).

Family Pyralidae, the Pyralids. This is the third largest family in the order and includes many destructive species, some important ones being the European corn borer, sod webworms, pickleworm, melonworm, garden webworm, and the meal moths. Most of the members of this family are small brown moths with darker markings, often with gray mottling (Fig. 39). The destructive species are illustrated and described in succeeding chapters.

Order Coleoptera, the Beetles. This is the largest order of insects, approximately 40% of all species being beetles. Its members are easily

Fig. 39. The beet webworm, *Loxostege sticticalis* (L.), a member of the family Pyralidae. (U.S.D.A.)

recognized by their hardened, opaque front wings, called elytra, which meet in a straight line down the back. The second pair of wings are membranous and folded beneath the first pair. They have chewing mouthparts, their metamorphosis is complete, and their antennae are of various types. Larvae have well-developed heads and jaws, usually three pairs of true legs but no prolegs, with a wide diversity of form and habits. The larvae of snout beetles or weevils are entirely footless. Pupae are usually naked and the appendages are free. The order includes a large number of families many of which have considerable economic importance. Representative families are briefly discussed.

Family Cicindelidae, the Tiger Beetles. These long-legged beetles are brightly colored, often metallic, with five tarsal segments on all legs. The antennae are filiform and the head is usually wider than the prothorax. They are predatory in both the larval and the adult stages.

Family Carabidae, the Ground Beetles. These active beetles are usually black, nocturnal, and predatory. They have five tarsal segments on all legs, and the head is narrower than the prothorax. Antennae are filiform. The family is a large one, and the aggregate effect of the activities of the many predators is certainly great, though not accurately known.

Family Coccinellidae, the Lady Beetles. All are nearly hemispherical, often brightly colored, marked with spots, with three tarsal segments on all legs (Fig. 40). Many are very small and little noticed; others are larger, reaching nearly $\frac{3}{8}$ inch in length. All but two species, the bean beetle and squash beetle, are predatory, and the family is justly regarded as one of highest value to man.

Family Lampyridae, the Fireflies. This is an interesting group of

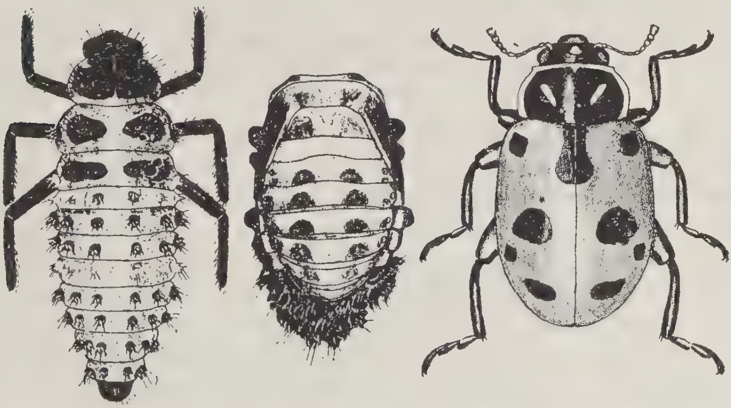

Fig. 40. Larva, pupa, and adult of the lady beetle, *Hippodamia sinuata* Mulsant, family Coccinellidae. (Smith, Idaho Agr. Exp. Sta.)

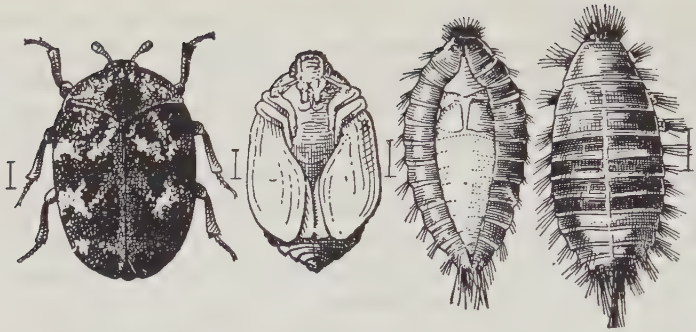

Fig. 41. Adult, pupa, and larva, of the carpet beetle, *Anthrenus scrophulariae* (L.), family Dermestidae.

beetles, some of which have light-producing organs in both the larval and adult stages. The familiar "lightningbugs" of summer constitute one of the most common species. They are predaceous on other insects and are therefore beneficial. The larvae are called "glowworms."

Family Cantharidae, the Soldier Beetles. Elongate, soft-bodied, brown or black beetles, ranging in size up to nearly $\frac{3}{4}$ inch in length, comprise this family of predaceous insects. The soldier beetle resembles the firefly, but it does not have light-producing organs and its head is not concealed by the pronotum.

Family Staphylinidae, the Rove Beetles. These beetles are all slender and elongate, with very short elytra. They are usually associated with decaying animal or vegetable matter, but recent studies show them to be predaceous on the insects occurring in such materials.

Family Silphidae, the Carrion Beetles. These beetles are important to man in that they help eliminate dead animals, being scavengers. Broad, drab oval species, and red and black elongate forms are most commonly found.

Family Dermestidae, the Skin Beetles. Beetles in this family are usually quite small and are scavengers as well as pests in the household. Included in the group are the carpet beetles, larder beetles, and hide beetles. Some are black, others mottled with gray. The larvae are all quite hairy (Fig. 41). Adults feign death when disturbed.

Family Tenebrionidae, the Darkling Beetles. Tenebrionids resemble ground beetles but have thickened antennae and only four segments in the hind tarsi. Some species are scavengers, others destroy stored products, especially grains. The larvae of a few species resemble wireworms and are called false wireworms (Fig. 42).

Family Scarabaeidae, the Scarab Beetles. This is a large family of

Fig. 42. A false wireworm, *Eleodes suturalis* (Say), family Tenebrionidae. (Walton, U.S.D.A.)

beetles varying considerably in size, form, color, and habits. Some species are scavengers, others are destructive crop pests. Some of the best-known forms are the May beetles, Japanese beetles, rose chafers, and dung beetles. They are all robust beetles with inconspicuous lamellate antennae and usually with five tarsal segments on all legs (Fig. 102).

Family Elateridae, the Click Beetles. This family consists of elongate, hard-bodied beetles, with serrate antennae, which are capable of flipping themselves into the air when accidentally turned on their backs. This flipping continues until they land upright on their feet. Their slender, cylindrical, brown-to-yellow larvae are called wireworms and are important crop pests feeding on roots and tubers (see Fig. 108).

Family Chrysomelidae, the Leaf Beetles. A great variety of species occur in this family, some brightly colored, others drab; some are nearly 12 mm. in length, others about 1 mm. They are usually oval in form with four-segmented tarsi on all legs, the third segment bilobed. Both adults and larvae of some species attack foliage; others feed only on the roots in the larval stage. The rootworms, flea beetles, and cucumber beetles are common representatives (Fig. 43).

Family Cerambycidae, the Long-Horned Beetles. Larvae of these rather large beetles are called roundheaded borers. The adults are elongate, having unusually long antennae, with five tarsal segments which appear as four because the fourth is extremely small and concealed. Most species

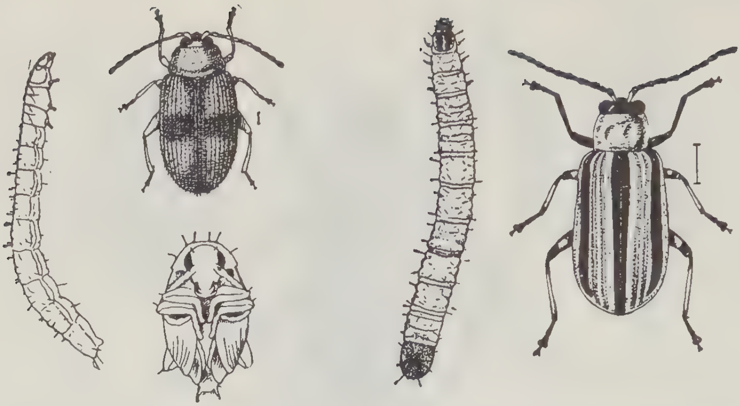

Fig. 43. Typical Chrysomelidae: (left) the tobacco flea beetle, *Epitrix hirtipennis* (Melsh.); (right) the striped cucumber beetle, *Acalymma vittatum* (F.). (U.S.D.A.)

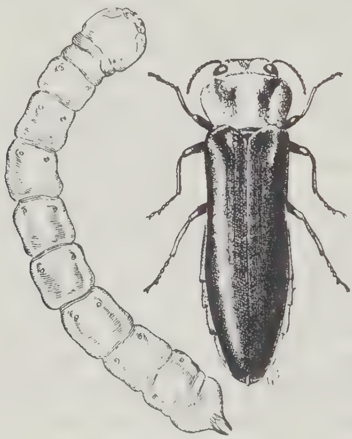

Fig. 44. The apple root borer, *Agrilus vittaticollis* (Rand.), family Buprestidae. (Brooks.)

are over ½ inch in length; some are nearly 4 inches. The adults feed on foliage and pollen, and the larvae tunnel the heartwood of trees. A few species are pests of wooden structures (see Chapter 16).

Family Buprestidae, the Metallic Wood Borers. These dark metallic beetles are extremely hard-bodied; some narrow and elongate, others broad and flattened, all tapering posteriorly. Anterior segments of the larvae are often expanded and flattened; hence the common name flatheaded

borers is used to describe them (Fig. 44). Larvae usually feed under the bark and in dead or dying trees, although some species attack newly transplanted or unthrifty trees. Other woody plants are also attacked by some species.

Family Nitidulidae, the Sap Beetles. Most of the members of this family are small beetles that feed on the sap from tree wounds, damaged fruits and vegetables, and fermenting plant fluids of decaying fruits and vegetables; a few are found in flowers or with fungi, and some are associated with dead animals. They are often black; a few are spotted. The elytra are short, exposing the terminal segments of the abdomen. Pest species are discussed in detail on p. 182.

Family Meloidae, the Blister Beetles. Most of the beetles in this family are around 1 inch or more in length, black, gray, or striped, with a narrow, elongate, soft body, and the head wider than the pronotum. The elytra are rounded over their cylindrical bodies. Larvae are predators, feeding on grasshopper eggs and other soil insects. The adults are foliage feeders, and are often quite destructive (Fig. 45). Blister beetles contain a substance known as cantharidin, which may blister human skin when the beetles are handled. Hypermetamorphosis is also characteristic of the group, which means that two or more distinct types of larvae occur in the life cycle, these generally being active and sedentary forms.

Family Bruchidae, the Pea and Bean Weevils. Small insects infesting the stored seeds of leguminous plants are members of this family. Some species begin their work in the developing seeds in the field. They are short stout beetles with truncated elytra, and the head is prolonged into a short, broad snout.

Family Curculionidae, the Weevils. Many of our most serious crop pests belong to this family. They are also known as snout beetles or

Fig. 45. Blister beetles, family Meloidae. (U.S.D.A.)

Fig. 46. Maize billbug, *Sphenophorus maidis* Chittenden, family Curculionidae. (U.S.D.A.)

a *b* *a* *b*

Fig. 47. Weevils, family Curculionidae; (left) the grape curculio, *Craponius inaequalis* (Say), and, (right) the plum curculio, *Conotrachelus nenuphar* (Hbst.); *a,* larva; *b,* beetle. (U.S.D.A.)

curculios because of the elongate curved snouts on the head, at the tip of which are the chewing mouthparts. Adults are hard-bodied, usually dark colored, and feign death when disturbed. Larvae are white, thick-bodied, footless grubs. Both beetles and grubs may attack almost any part of the host, but the grubs more commonly feed within the plant whereas the beetles work externally (Figs. 46 and 47).

Family Scolytidae, the Bark and Ambrosia Beetles. This group of rather small beetles with stubby snouts generally attacks woody plants, often boring beneath the bark in the cambium region. Both adults and larvae do damage, and death of the host usually results from girdling. Many important pests of forest, shade, and fruit trees belong to this family. Some common species discussed later are the shot-hole borer, peach bark beetle, and elm bark beetle. Ambrosia beetles tunnel deeply into the heartwood of trees. Their feeding is on fungi, which they cultivate in their galleries.

Order Diptera, the Flies. Distinguishing characters for the flies are the following: two membranous wings or none, a pair of halteres, complete metamorphosis, and a variety of antennal types and mouthparts. The larvae are footless, with the head and mouthparts greatly reduced in most species. Both large and minute species are represented in this extensive order. Their habits are quite variable, some being predators or parasites of insects, some attacking man and domestic animals, some being vectors of disease-producing organisms, some scavengers, and some important plant pests. The number of families is large, and only a few can be mentioned.

Family Tipulidae, the Crane Flies. These are large, long-legged flies, resembling giant mosquitoes. They develop in damp habitats high in organic matter.

Family Chironomidae, the Midges. This family consists of many species of small mosquitolike flies. They often hover in swarms at dusk and generally occur near swampy areas. The larvae of most midges are aquatic.

Family Simuliidae, the Black Flies. Small, dark hump-backed flies, with scant venation in the wings and a vicious bite, make up this family (Fig. 48). The larvae develop in flowing streams. In Mexico and Central America they are vectors of a filarial worm that causes onchocerciasis in man (see p. 645).

Family Culicidae, the Mosquitoes. This group includes many small, slender-bodied, long-legged flies with plumose antennae. The males have much larger and more densely plumed antennae. Mosquitoes are separated from similar flies by the tiny scales attached to the wing margins and to each wing vein (Fig. 49). The females are blood-sucking, and many species are vectors of the organisms causing dreaded diseases, namely, dengue, malaria, and yellow fever.

Family Cecidomyiidae, the Gall Gnats. These are also small flies resembling mosquitoes. They have long moniliform antennae, reduced wing venation and relatively long legs. Some species are predaceous, some scavengers, and some destructive plant pests, many of which cause

the formation of galls. Some common species are the wheat midge, sorghum midge, chrysanthemum midge, and the hessian fly.

Family Tabanidae, the Horse and Deer Flies. The females of these flies are vicious biters, feeding on the blood of livestock and man. Horse flies are large, some being $1\frac{1}{2}$ inches in length; deer flies are usually near $\frac{1}{2}$ inch in length. Both species have semiaquatic larvae, and development takes place therefore in swamps, marshes, and along streams.

Fig. 48. A black fly, *Simulium vittatum* Zett., family Simuliidae. (Knowlton and Rowe, Utah Agr. Exp. Sta.)

Fig. 49. A salt-marsh mosquito, *Aedes sollicitans* (Walker), family Culicidae. (Smith, N. J. Agr. Exp. Sta.)

Family Bombyliidae, the Bee Flies. These are parasitic flies, the larvae feeding on various caterpillars and grasshoppers. The adults resemble bees and are often found on flowers.

Family Asilidae, the Robber Flies. These rather large flies are predaceous on insects in both the larval and adult stages. The top of the head is hollowed out between the large compound eyes, and the abdomen is often long and tapered to a point. Many of these flies are quite hairy, with long legs equipped with spines and bristles.

Family Syrphidae, the Syrphid or Flower Flies. This family includes both small and large species, some reaching over an inch in length. They are generally black or brown with yellow stripes. Many resemble wasps or honey bees. The larvae are important predators of aphids and other small insects; the adults commonly are found hovering about flowers. The

Fig. 50. The Mediterranean fruit fly, *Ceratitis capitata* (Wied.), family Tephritidae. (U.S.D.A.)

Fig. 51. The ox warble fly, *Hypoderma lineatum* (de Villers), family Oestridae, female. (Riley and Howard, *Insect Life*.)

adult is distinguished by the spurious vein between the radial and medial veins.

Family Tephritidae, the Fruit Flies. These flies are all about the size of the house fly, and are recognized by the dark bands or spots on their wings. The larvae or maggots are the destructive stage. Some common species are the apple maggot, cherry maggot, and the Mediterranean fruit fly (Fig. 50).

Family Gasterophilidae, the Horse Bot Flies. These flies resemble honey bees. Their abdomen is rather pointed and usually curves under. The larval stages are important endoparasites of the alimentary tract of horses.

Family Oestridae, the Warble Flies. In this group are the important livestock pests, the sheep grub, and the ox warbles or cattle grubs (Fig. 51). They are described in detail in a later chapter.

Family Tachinidae, the Tachinid Flies. These are small-to-rather-large hairy flies, usually with the arista bare (Fig. 52). They are parasitic on a wide variety of our pest insect species and undoubtedly play an important role in checking destructive outbreaks.

Family Calliphoridae, the Blow Flies. This group includes the metallic blue or green flies commonly associated with dead animals. Some species lay their eggs in wounds and subsequent development may result in death of the animal. The screw-worm fly is an example of a species with this habit.

Fig. 52. *Winthemia leucaniae* (Kirk.), left, side view of head, center, and *Triachora unifasciata* (R.-D.), right, family Tachinidae, parasites of caterpillars. (Riley.)

Fig. 53. The little house fly, *Fannia canicularis* (L.), family Muscidae. Female left, male right. (U.S.D.A.)

Family Muscidae, the Muscids. This family includes the face fly, house fly, horn fly, stable fly, tsetse fly, and many others (Fig. 53). The horn, stable, face, and house flies are well-known species in this country, and a detailed discussion of their life cycles and control is given in Chapter 23.

Family Anthomyiidae, the Anthomyiids. These flies resemble house flies but are slightly smaller. Several species are very important plant pests, some common examples being the cabbage maggot, seed corn maggot, onion maggot, and the beet leaf miner. These are discussed in detail in subsequent chapters.

Family Hippoboscidae, the Louse Flies. Winged species attack birds;

the common wingless species is the sheep ked, an important ectoparasite of sheep. Their body is brown, flattened, and leathery, the mouthparts piercing-sucking, and reproduction truly viviparous.

Order Siphonaptera, the Fleas. These are brown, laterally flattened, wingless insects, with well-developed jumping legs and piercing-sucking mouthparts. The adults suck blood from birds and mammals, and some species are vectors of the organisms causing bubonic plague and endemic typhus. Metamorphosis is complete, the larvae developing in organic material consisting primarily of adult flea excrement, skin scales, and scabs of the host (see Chapter 23).

Order Hymenoptera, the Bees, Wasps, and Ants. This large group of insects is characterized by having four membranous wings or none, complete metamorphosis, and chewing or chewing-sucking mouthparts. The larvae are legless and grublike except for some sawflies; their larvae resemble lepidopterous caterpillars but can be distinguished from them by the six to eight pairs of abdominal prolegs without crochets. A variety of habits are represented in the order. Some attack plants, devouring foliage, mining leaves, boring in wood, or causing galls to form. Others are predaceous or parasitic on insects, pollinators of plants, or producers of honey and beeswax. Social behavior is highly developed in some groups of bees, wasps, and ants. The order is arranged into superfamilies for convenient discussion.

Superfamily Apoidea, the Bees. Bees usually have modified hind tarsi

Fig. 54. *Sphex atratus* Lepeletier, family Sphecidae, a digger wasp, which provisions its nest with stung and stupefied grasshoppers. (Walton, U.S.D.A.)

and branched hairs on the body, but some species are less hairy on the abdomen. Females of most species have a well-developed sting. The group is ranked as very important in the pollination of agricultural crops and the production of honey and beeswax. Some common species are honey bees, bumble bees, and leafcutter bees.

Superfamily Sphecoidea, the Digger Wasps and Others. Quite a variety of wasps are ascribed to this group. It includes the thread-waisted forms, cicada-killers, mud-daubers, several mining species, and others. Many are predatory, capturing caterpillars, other insects, and spiders which serve as provision for their young (Fig. 54). A few species are parasitic on homopterous insects. They probably aid materially in the control of some pests. Wasps have unbranched hairs on the body.

Superfamily Vespoidea, the Social Wasps. Some of these wasps are predators and some are minor pests about dwellings. The family can scarcely be considered as an economic group. Hornets, yellow jackets, spider wasps, and paper wasps are the best-known species.

Superfamily Formicoidea, the Ants. Several species of ants which are listed as pests are illustrated and discussed in subsequent pages. Many, not mentioned, are doubtless important predators. It seems possible that the greatest importance of ants is based on the predatory habits of many

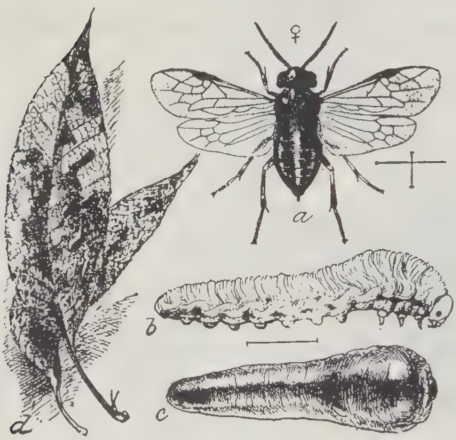

Fig. 55. Complete metamorphosis in Hymenoptera. The pear slug, *Caliroa cerasi* (L.). Note the prolegs on the caterpillar-like larvae common among the sawflies. *a*, adult female sawfly; *b*, larva with slime removed; *c*, same in normal state; *d*, leaves with larvae. (U.S.D.A.)

Fig. 56. *Aphidius avenaphis* (Fitch), a parasite of aphids, and the body of the host showing the exit hole of the adult parasite; family Braconidae. (J. B. Smith.)

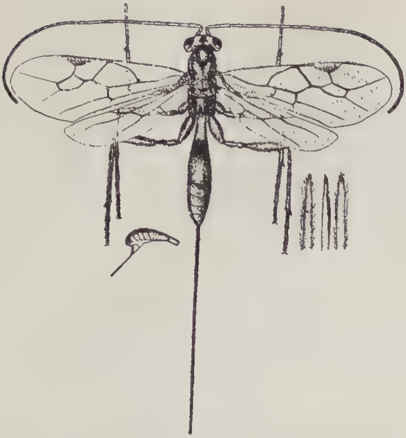

Fig. 57. *Macrocentrus ancylivorus* Roh., a braconid parasite of several caterpillars. (Fox, U.S.D.A.)

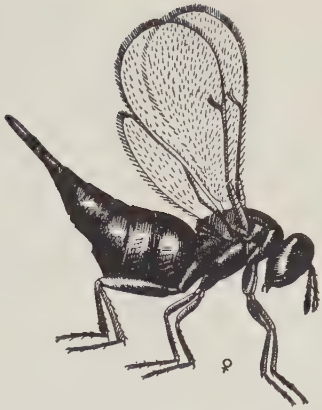

Fig. 58. *Aprostocetus diplosidis* Crawford, a chalcid parasite of the sorghum midge.

rather obscure species. All ants are social and each colony contains a queen, males, and workers.

Superfamily Tenthredinoidea, the Sawflies. These insects have the abdomen broadly joined to the thorax, rather than constricted, the latter characteristic of almost all the other members of the order. Their larvae also differ widely from the helpless young in other families. Sawfly larvae are caterpillar-like but have six to eight pairs of abdominal prolegs in place of the five pairs possessed by true caterpillars. Prolegs of sawfly larvae have no crochets. Some species are small, a few are large, but more commonly the sawflies are of medium size. Defoliation and leafmining are common habits of the larvae (Fig. 55).

Superfamily Cynipoidea, the Gall Wasps. These are tiny black wasps with the abdomen laterally compressed and the posterior segments appearing telescoped. Some species are parasitic, but the majority attack plants, causing the development of tumor-like growths or galls. Oaks, rose, and blackberry are some of the common hosts.

Superfamily Ichneumonoidea, Ichneumon and Braconid Wasps. The largest of the common parasitic species belong to the family Ichneumonidae. It includes numerous species and is regarded as one of the most beneficial families of insects. Adults are long, narrow-bodied, wasplike insects, with sixteen or more segments in the antennae, two recurrent veins in the fore wings (Fig. 70), and a long prominent ovipositor on the females. The equally important family Braconidae comprises similar but smaller insects with only one recurrent vein in the fore wings (Figs.

56 and 57). Pupation often takes place in silken cocoons outside the body of the host (Fig. 34). Both ichneumons and braconids attack many caterpillars, beetle larvae, aphids, and spiders.

Superfamily Chalcidoidea, the Chalcid Wasps. Most chalcids are small; many very minute. Some are crop pests, but a great number are parasitic in the eggs and other developmental stages of moths, flies, beetles, and homopterous insects. They are frequently metallic black, broad-headed, with scarcely any wing venation (Fig. 58). This group ranks with the preceding one in importance to man.

Superfamily Proctotrupoidea, the Proctotrupids. This is the third major aggregation of parasitic insects. Most of the species are quite small and practically all are parasitic on other insects. The number that attack crop pests is enormous.

Species, among the small parasites, are usually identified only by specialists in the groups. Illustrations of parasites throughout this book will serve to acquaint the student with the more common species. In order to show the minute detail of these small insects the figures are greatly enlarged.

4

Natural Insect Control

The equilibrium that exists at any particular time among all the acting forces of nature has been termed the "balance of nature." These interacting forces can be grouped into two categories based on whether they promote or limit population growth.

The forces or factors that promote population growth of an insect, or any animal, are sometimes called its *biotic potential* or ability to reproduce itself in the absence of destructive elements. The important factors are length of life cycle, number of generations per year, sex ratio, fecundity, and polyembryony. An insect that has a sex ratio of one, that is polyembryonic, that lays many eggs or gives birth to many young, that has a short life cycle with repeated generations developing throughout the year possesses a high biotic potential.

The combined factors that tend to destroy or limit populations of insects have been called *environmental resistance*. They can be grouped into climatic, topographic, and biotic factors, and they are the subject of discussion in this chapter.

Natural control can be defined as any condition of the environment that checks insect populations and cannot be altered at will by man, at least on an extensive scale. Natural control encompasses all the factors mentioned under environmental resistance.

Climatic Factors. Temperature is perhaps the most important factor in climatic influence on insects. Its extremes prevent the existence of certain species in some regions or, if it does exist, the insect is unable to maintain a population great enough for its activity to be noticed by man. The exposed life stages of insects are especially vulnerable. Prolonged periods of high (110 to 125° F.) or low (—20° F.) temperatures greatly affect insect populations. Sudden changes in temperature also bring about control. For example, in the autumn a killing frost will eliminate the food plants of certain insects before they have reached the usual stage for overwintering. Or a warm period in the early spring stimulates hormonal activity of overwintering life stages to the point that they pass into the next stage,

and these are then killed by a rapid temperature drop to freezing or below.

Extremes of moisture, atmospheric humidity, soil moisture, and rainfall likewise act as checks or as favorable factors, depending on the insect species. Heavy rainfall may flood areas, killing many species or, accompanied by strong winds, may strike small, soft-bodied insects with such force that they will be washed from the plants and killed. The hibernating quarters of many species are greatly affected by an excess of moisture. A heavy snowfall acts as an insulating layer and actually protects life stages in hibernation, so that lack of snow in cold areas often results in lower populations. Humidity is a very important factor since the proper range is necessary for the development of naturally occurring fungi, bacteria, and viruses which invade and kill insects. It is also essential for normal hatching, molting, and emergence.

Air currents or high winds may aid in the distribution of insects or be limiting factors in their numbers. Likewise sunlight and atmospheric pressures exert some influence on insects and their behavior and may be partly responsible for the size of a population in a given area.

Combinations of all these climatic factors operate to bring about natural control of insects.

Topographic Factors. These include the barriers that interfere with free migration from one region to another. Oceans, mountain ranges, deserts, broad rivers, and zones with prohibitively unfavorable climate make up the list of natural barriers. In addition, the physical and chemical nature of the soil has a direct bearing not only on the suitability of the environment for insects but also on their food supply.

Biotic Factors. All the factors of a biological nature that contribute to natural control of insects are usually placed in this category. They may be divided into the following groups: predators, parasites, natural resistance of plants or animals to attack by insects, and competition between the same or different species.

A *predator* may be defined as a living, active animal which catches and devours usually smaller or more helpless organisms or animals (called prey), killing them very soon after capture and requiring many individuals throughout its life cycle for proper nourishment and normal development. For example, a lady beetle feeds on many aphids or plant-lice in both the larva and adult life stages during its life span.

Birds are perhaps the most widely known of the predators which contribute to the reduction of insect populations, but they are probably not the most important. The value of the group in nature, unaffected by the activities of man, is undoubtedly much greater than it usually is under conditions imposed by intensive agriculture. Nevertheless, many birds feed

very largely upon insects, and they should be encouraged in every practical way. Some common species that are often considered important predators of insects are: swifts, wrens, warblers, nighthawks, gulls, killdeers, woodpeckers, meadowlarks, orioles, starlings, blackbirds, quail, and sometimes robins and catbirds.

Many mammals such as hogs, bats, moles, shrews, mice, skunks, and even squirrels eat insect life stages. Even man may be considered a predator in those countries where certain insect species serve as food. For example, the eggs of May beetles and the larvae of a Papilio butterfly attacking the maguey plant in Mexico are often eaten by the natives.

In the amphibia we have the frogs, toads, and salamanders, which consume many insects. Usually the work of these animals is of importance only in small gardens, but occasionally toads, at least, have proved useful on a large scale.

A number of species of reptiles feed upon insects, but their actual influence on the populations of any important pest has not been demonstrated. Many fish feed almost exclusively upon insects, some of which are pest species like the immature stages of mosquitoes, and others feed on aquatic forms not considered pests but valuable to man in that they serve as food for edible fish.

Invertebrates that attack insects are almost all in the phylum Arthropoda. Spiders are probably the most important of all noninsect predators of insects. The main disqualification of spiders as beneficial predators is that they feed on a wide variety of insect food and rarely concentrate enough on any one pest to accomplish a notable degree of control. Harvestmen, mites, and scorpions, in the same class as the spiders, are with some exceptions predatory.

In the class Chilopoda, the centipedes are classified as predatory animals, and their food is largely insect.

In the aggregate insects predaceous on insects become more numerous and are far more valuable than all the other groups of predators combined. Insect predators are found in many orders and are represented by a large number of families. Some families are mainly predaceous; others include only occasional species that have this habit. To single out accurately the most important family of predators, among the insects, is difficult with the present state of our knowledge. However, many authorities on the subject rank the lady beetles high in this respect in spite of the fact that there are a few species that are plantfeeders.

Beetles comprise approximately 40% of all insect species on the earth, and as a group include many species that feed on other insects. Two outstanding families are the lady beetles (Coccinellidae) and the ground beetles (Carabidae). Lady beetles (Figs. 59, 60, and 61) are a large group, widely

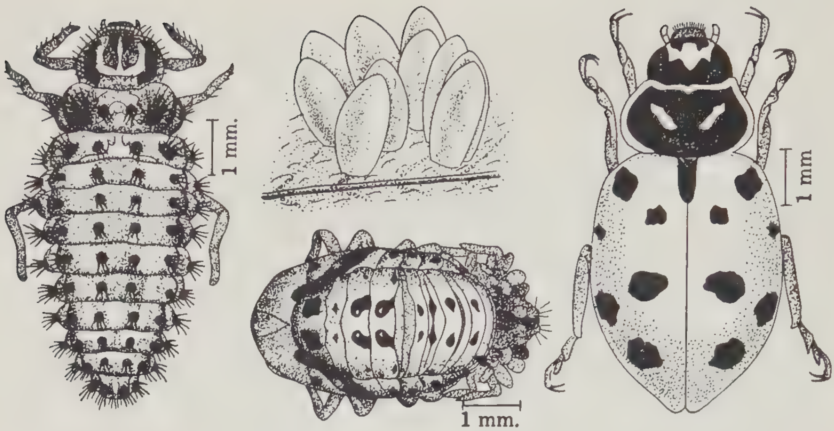

Fig. 59. The convergent lady beetle, *Hippodamia convergens* Guérin; eggs, larva, pupa, and adult, family Coccinellidae. (Prince, Kansas Agr. Exp. Sta.)

Fig. 60. Larva, pupa, and adult of the spotted lady beetle, *Coleomegilla maculata* (DeGeer), a widely distributed species attacking many aphids. (U.S.D.A.)

distributed, active in both larval and adult stages, with a considerable range of prey which includes some of our most destructive insects, notably the aphids, scales, and mealybugs. Ground beetles (Fig. 62) are for the most part relatively large, active predators, and some species become quite numerous. The fact that they often feed at night tends to detract from an appreciation of their activity and value. Caterpillars are probably

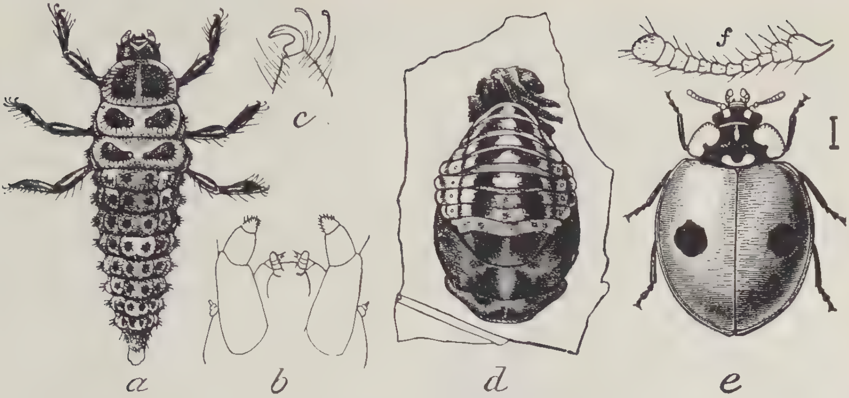

Fig. 61. The two-spotted lady beetle, *Adalia bipunctata* (L.): *a*, larva; *b*, mouthparts; *c*, claw; *d*, pupa; *e*, adult; *f*, antenna; all enlarged. (Marlatt, U.S.D.A.)

preferred hosts, but many life stages of insects are destroyed by both adults and larvae. Other beetles predatory in habit are the soldier beetles (Cantharidae), fireflies (Lampyridae), rove beetles (Staphylinidae), and the larvae of several blister beetles (Meloidae), which feed on the eggs of grasshoppers and play an important role in grasshopper control. Tiger beetles (Cicindelidae) in both the larval and adult stages, likewise are active as predators on insects.

Fig. 62. *Calosoma scrutator* (F.), a ground beetle; an active predator on caterpillars.

The true bugs include quite a number of first-class predatory species. Many species of stink bugs attack various harmful insects. Assassin bugs are all predatory but tend to attack species other than crop pests. A few members, however, are important enemies of potato beetle and asparagus beetle larvae, and other caterpillars on crop plants. A very small member of a rather obscure family of bugs (Anthocoridae) is one of the really valuable predators. This is *Orius insidiosus* (Say) (Fig. 22). Another family of predatory bugs is the damsel bugs (Nabidae), of which *Nabis americoferus* Carayon is a well-known representative attacking crop pests to an effective extent. The ambush bugs (Phymatidae) are represented by a few com-

Fig. 63. Adult and larva of *Syrphus ribesii* L., a widespread predator on aphids, with enlargements of the anterior and posterior spiracles of the larva. (Natural size about that of the house fly.)

Fig. 64. *Aphidoletes meridionalis* Felt, a cecidomyid fly. (Left) adult female, *a*, antenna of male, and *b*, abdomen of male. (Right) larva attacking a pea aphid (Walton, U.S.D.A.)

mon species that attack a number of insects, beneficial as well as destructive ones. A plant bug, *Cyrtorhinus mundulus* (Bredd.) (family Miridae), is known to be an important predator of sugarcane leafhopper eggs.

Many predatory flies are known. The most important are the syrphid fly larvae (Syrphidae), which are active enemies of aphids (Fig. 63) and occasionally attack other insects. The adults of robber flies (Asilidae) are considered to be of some importance, and destroy a number of insect species. Dipterous predators in other families are predaceous either as larvae or adults but are less important to agriculture so far as we now know (Fig. 64).

Lepidopterous predators are almost nonexistent. The larvae of some butterflies (Lycaenidae) are recorded as feeding on scale insects, leafhoppers, aphids, and treehoppers. A moth larvae (Pyralidae) is also recorded as predatory on unarmored scale insects.

Many ants (Formicidae) are predaceous in habit in spite of the fact that they are thought of mainly as pests. They are omnivorous and readily become scavengers when insect food becomes scarce. Ants are more

Fig. 65. (Left) larva of a robber fly, *Promachus vertebratus* (Say), attacking a white grub; (right) larva of a ground beetle feeding on a cutworm. (Davis and Crumb, U.S.D.A.)

Fig. 66. *Promachus vertebratus* (Say), an asilid predatory on white grubs, and *Pyrgota undata* Wied., a parasitic fly. (U.S.D.A.)

universally distributed probably than any other predators and doubtless far exceed in total numbers any insects approaching them in size. Besides the ants, there are other hymenopterous insects which are considered valuable predators. These are the wasps in the families Sphecidae and Vespidae.

The praying-mantids are entirely predatory and, although they are rather large and clumsy, they destroy numerous insects during their life cycle. They are the most important predators in the order Orthoptera. Both roaches and crickets have been known to feed upon other insects which they have captured and killed, but the habit is not common or extensive enough to reflect any particular credit on these usually pestiferous groups.

Among the members of the minor orders are a few groups which are effective and valuable predators. The lacewings (Chrysopidae) are perhaps the most important of these; their larvae are predators of aphids and are called aphid-lions. Thrips are usually plant pests, but the order Thysanoptera includes predatory species of considerable value. The young dragonflies, in their aquatic habitat, destroy other insects including quantities of mosquito larvae. Other aquatic forms may have slight value in the same way. Although many other insects are predatory, there are none which has been proved to have any measurable effect on pest populations.

The aggregate effect of predator populations cannot yet be measured or even estimated with a great degree of accuracy, but there is no doubt that they play a very important role in keeping certain insect populations in check.

A *parasite* is defined as an organism that lives in or on another usually larger living organism (host), and requires only one or a partial individual to complete its life cycle. For example, in some aphid parasites, only one

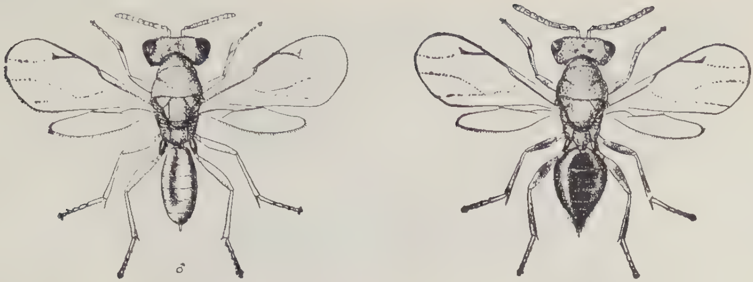

Fig. 67. *Pteromalus puparum* (L.), a chalcid that parasitizes the cabbage worm and many other injurious insects; male and female, greatly enlarged. Hairline shows natural size. (U.S.D.A.)

individual develops in each aphid, whereas many braconid parasites may develop in a single caterpillar such as the tomato hornworm. In some kinds of parasitism, the host does not die, for example, a bed bug on man or a tapeworm in man, but usually death is the end result of insects parasitic on insect species, although it is not immediate. The insect parasites of insects are often called *parasitoid* species.

There are various kinds of parasites. When they attack the host externally they are known as *ectoparasites,* when internally they are known as *endoparasites. Permanent* parasite is descriptive of a species that spends all life stages on the host whereas an *intermittent* parasite is on the host only at feeding time. A *primary* parasite is any species attacking a particular host, and it is considered beneficial to man if the host is a destructive insect. A parasite that attacks another parasite is called a *hyperparasite.* When hyperparasites are abundant they may completely counteract the beneficial effects of a primary parasite. If the host is attacked by many individuals of the same parasite species, *superparasitism* results; when

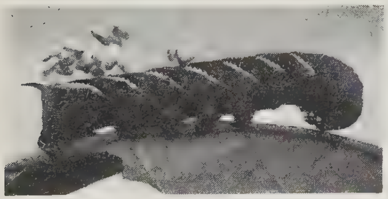

Fig. 68. Braconid cocoons attached to hornworm host. (Marcovitch, Tenn. Agr. Exp. Sta.)

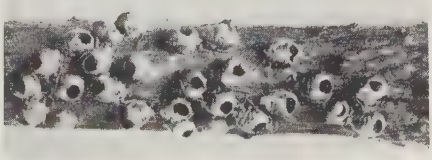

Fig. 69. Remains of aphids from which braconid parasites have emerged. The body wall of the host serves as a cocoon. (McDaniel, Mich. Agr. Exp. Sta.)

Fig. 70. *Itoplectis conquisitor* (Say), an ichneumon parasite of many caterpillars. (Pettit, Mich. Agr. Exp. Sta.)

attacked by more than one species of a primary parasite the term applied is *multiple parasitism.*

The parasites of insects are conveniently grouped in the following categories: insects, nematodes, protozoa, bacteria, fungi, and viruses. The last four groups are usually thought of as pathogens that produce diseases of insects.

On the whole, insects are generally considered the most important group of parasites that reduce insect populations. They are to be found in several orders, two of which are outstanding, Hymenoptera and Diptera.

There are many hymenopterous families which include species for the most part parasitic in habit. These have been discussed in Chapter 3, but further mention here seems appropriate.

The superfamily Chalcidoidea is composed of some fifteen to twenty families, all more or less closely related. The vast majority of the species are parasitic in their larval stages on the eggs and larvae of other insects, The genus *Aphelinus* contains species that parasitize aphids and scales; the genus *Aphycus* contains species parasitic on scale insects, and the genus *Pteromalus* contains species that parasitize the chrysalids of cabbage butterflies and related forms. *Trichogramma evanescens* Westwood and *T. minutum* Riley are egg parasites of considerable importance. They are minute wasps just large enough to be seen by the unaided eye. Their importance is based on the fact that, unlike many parasites, they have a large number of possible hosts and therefore should be more widely distributed and present most of the time.

Fig. 71. (Left) *Horogenes plutellae* (Viereck), an ichneumonid parasite of the diamondback moth, and, (right) *Spilochalcis flavopicta* (Cresson), a hyperparasite attacking the ichneumon. (U.S.D.A.)

In the superfamily Ichneumonoidea are many important parasitic species. The rather large ichneumon wasps of the genera *Ophion, Itoplectis* (Fig. 70), and *Pimpla* are among the more common parasites of caterpillars. Other genera such as *Apanteles, Microbracon, Ascogaster, Chelonus,* and *Macrocentrus* are all likely to attack caterpillars. The last-named includes parasites of the European corn borer, codling moth, and oriental fruit moth. *Apanteles glomeratus* (Linn.) is a well-known parasite of the larvae of the cabbage butterfly. The almost universal aphid parasite is *Aphidius testaceipes* (Cresson). It reproduces throughout the summer and is an effective check on many species of plant-lice.

Parasitic flies are often more important enemies of insects than are the Hymenoptera. *Blaesoxipha kellyi* (Aldrich) (Sarcophagidae) and several related species attack grasshoppers, very effectively at times. *Winthemia quadripustulata* (Fabr.) has a large number of caterpillar hosts and usually succeeds in keeping several of them under complete subjugation. It is a tachina fly. Another species in the family Tachinidae is *Trichopoda pennipes* (Fabr.). This is an important species and of special interest because of its somewhat unusual host range. True bugs, such as the squash bug, and beetles are both on the list. A third member of this family is *Exorista larvarum* (L.), which attacks a wide variety of hairy caterpillars. Fly parasites of less importance are found in the families Pipunculidae, Phoridae, Bombyliidae, and Pyrgotidae.

Although insect parasites are known in other orders, none of them affects any great destruction among the major pests.

The nematodes have been studied and have proved on occasion to be controlling factors for some injurious insects. Some species attack boll

Fig. 72. *Tomosvaryella subvirescens* (Loew), parasitic on adults and nymphs of beet leafhopper. (Knowlton, Utah Agr. Exp. Sta.)

Fig. 73. *Megaselia perdita* (Mallock), a phorid parasite of the alfalfa caterpillar. (Walton, U.S.D.A.)

weevils, face flies, grasshoppers, cockroaches, bumble bees, leaf beetles, May beetles, various lepidopterous caterpillars, and bark beetles.

Many kinds of protozoa are associated with insects, but the greater part of those known to be pathogenic belong to the Microsporidia. A good example is *Nosema bombycis* Naegeli, which is the cause of the disease of silkworms known as pébrine. *Nosema apis* Zander causes a disease of adult honey bees. There are other species that are parasitic and cause disease in members of the orders Hymenoptera, Diptera, and Lepidoptera.

The bacteria rate high as parasites causing disease in insects. Some examples are: *Coccobacillus acridiorum* d'Herelle, which attacks grasshoppers; *Bacillus pluton* White, or European foulbrood, and *Bacillus larvae* White, or American foulbrood, both of which attack the brood of honey

Fig. 74. *Winthemia quadripustulata* (Fabr.), a tachinid parasite of caterpillars, showing eggs attached to armyworms. (Slingerland, Cornell Agr. Exp. Sta.)

bees; *Bacillus noctuarum* White, which attacks many lepidopterous caterpillars; *Bacillus popilliae* Dutky, the organism that produces milky disease of Japanese beetle larvae and also attacks other Scarabaeidae. These diseases are often sporadic and at such times greatly reduce insect populations. Environmental conditions undoubtedly control very largely the normal development of these diseases.

Many fungus diseases of insects are described, and some of them play an important role in controlling a number of our major pests. One of the best known is the fungus, *Beauveria globulifera* (Speg.), which has been recorded as occurring on more than 70 insect species in North America. This is the fungus that controls the chinch bug when the weather is warm and humid. These same conditions are necessary for the proper development of most fungi.

Some fungi that frequently attack scale insects and whiteflies on citrus trees include the brown fungus, *Aegerita webberi* Fawcett; the red fungus, *Aschersonia aleyrodis* Webber; the yellow fungus, *Aschersonia goldiana* (Saccardo and Ellis); the red-headed fungus, *Sphaerostilbe aurantiicola* (B. and B.); and the white-headed fungus, *Podonectria coccicola* (E. and E.); the latter is one of the first entomogenous fungi observed in Florida. *Entomophthora fumosa* Speare attacks mealybugs; *Acrostalagmus aphidum* Oud. attacks aphids; and the black scale fungus, *Myriangium duriaei* Montandon, which attacks San Jose scale as far north as Virginia, are other examples of fungi pathogenic to insects.

More generally distributed fungi are *Empusa muscae* Cohn, which attacks flies; *E. grylli* (Fres.), a very important factor at times in the control of grasshoppers and crickets; *E. aphidis* Hoff. which attacks aphids; and

Fig. 75. (Left) *Exorista larvarum* (L.), a parasite of the gypsy moth, and, (right) *Compsilura concinnata* (Meigen), also an important parasite of both gypsy and brown-tail moths. (U.S.D.A.)

Entomophthora sphaerosperma Fres. and *Beauveria bassiana* (Bals.) which have a variety of hosts.

The genus *Cordyceps* contains a large number of species, the majority of which parasitize insects. One species, growing on white grubs, produces a prominent stemlike external growth from the dead larvae. The muscardine fungus, *Metarrhizus anisopliae* Sorokin, destroys white grubs, wireworms, cutworms, European corn borer, and other caterpillars. *Sorosporella uvella* (Krass.) is parasitic in caterpillars.

The viruses comprise a group of important disease-producing organisms, and research in this area has been quite active during the past decade. Most authorities divide them into two groups, polyhedral and nonpolyhedral diseases. Of the 250 virus infections recognized in nearly 175 species of insects and arachnids, about 170 of these are nuclear polyhedroses, 30 are cytoplasmic polyhedroses, 35 are granuloses, and 8 do not appear to be associated with inclusion bodies of any kind. Some examples of polyhedroses are jaundice or grasserie of the silkworm and the so-called wilt diseases of various species of Lepidoptera larvae, such as cutworms, tent caterpillars, tussock moths, gypsy moth, cabbage looper, hemlock looper, armyworm, and alfalfa caterpillar. A virus disease of European pine sawfly has also been reported. Sacbrood of honey bees is the only well-known nonpolyhedral disease that has been studied to any extent. This disease is troublesome to the beekeeper. Two other virus diseases, pseudojaundice 1 and 2, have been reported attacking a species of cutworm, and these are of the nonpolyhedral type.

Resistance when applied to plants or animals, may be defined as any factor or group of factors existing from natural causes which deter insects or prevent them from attacking. Types of resistance have been categorized into nonpreference, tolerance, and antibiosis. The factors involved are not too well understood but are thought to be physical and physiological, and most often genetic in character. Any naturally occurring animal or plant species, or their varieties, which are not attacked by insects to the same degree may be said to possess natural resistance. Present-day plant hybrids resistant to insects had their beginnings in selections of some naturally occurring species that had exhibited resistance.

The last factor of a biotic nature to be considered is competition between the same or different species for a given food supply. Natural mortality results especially for immature insects which, lacking a means of rapid locomotion, are less able to find additional or substitute food.

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5

Applied Insect Control: Chemical

An applied control measure may be defined as any method employed by man to bring about reduction of an insect population. For convenience in our discussion the methods are divided into the following groups: chemical, mechanical, cultural, biological, and legislative. Some or all of these may serve when a high population of a harmful insect develops. The choice of method depends largely on its cost and effectiveness and the valuation of the crop or property to be protected. The ultimate goal of any control program is to shift an adverse "balance of nature" to one that favors man.

CHEMICAL CONTROL

One of the most important methods of controlling insects is by means of chemicals. Applications of chemicals for killing insects imply the use of insecticides. Since the word "insecticide" means insect-killer, it would seem to include any control measure that results in mortality of insects, but the usual interpretation is application of chemicals. The chemicals employed for killing mites are called *miticides* or *acaricides. Pesticide* is another term becoming more widely adopted to describe any chemical used for controlling various kinds of pests.

Chemicals for insect control are classified in various ways. A common method is to group them according to their type of action, for example, stomach poisons, contact poisons, fumigants, repellents, attractants, and chemosterilants.

Stomach Poisons

A stomach poison is a material taken internally through the mouth, producing its effect by absorption from the digestive tract. Insects with chewing-type mouthparts are more often killed by these poisons. However, some chemicals when applied to plants are absorbed into the plant system and produce poisonous sap, which will kill insects with either chewing or piercing-sucking mouthparts by stomach poison action. This

group of chemicals is called *systemic poisons.* They must decompose fast enough so that unsafe residues are not present in any portion of plants consumed as food or feed. Although some compounds listed as stomach poisons may have other types of action, the majority of them are primarily effective as stomach poison insecticides.

Arsenicals. The compounds of arsenic are considered to be the most important chemicals applied as stomach poison insecticides. Although the use of many of these compounds has been decreasing owing to the appearance of more effective and cheaper substitutes, they still hold an important place in the list of chemicals for insect control.

The arsenicals are manufactured primarily from the two oxides: arsenious oxide (As_2O_3) and arsenic oxide (As_2O_5). These materials in water form arsenious and arsenic acids, respectively. When reacted with basic compounds they form the corresponding salts. Those formed from arsenious acid are called "arsenites" and those from arsenic acid "arsenates." The arsenites are quite soluble in water, very toxic to both plants and animals, and are generally used in poisoned baits. The arsenates are the more stable product and the safer form to apply on plants.

Acid Lead Arsenate, $PbHAsO_4$, is the most widely used of the arsenic compounds, and one of the standard insecticides for apple orchard and shade tree pest control. It is toxic to a wide range of insects, adheres well to plant foliage, and usually does not injure plant foliage at the dosage required to kill the insects. It remains in suspension well when used as a spray and has good physical properties when used as a dust. It is compatible with nicotine sulfate, bordeaux mixture, lime-sulfur, wettable sulfur, fluorine compounds, and some oil emulsions; however, it cannot be used safely with most soaps in hard alkaline water because of the formation of soluble arsenic which is phytotoxic.

Basic Lead Arsenate, $Pb_4(PbOH)(AsO_4)_3 \cdot H_2O$, is an ingredient in most commercial acid lead arsenates. It is less toxic to insects and safer on plant foliage. It is applied principally in very humid areas of California and other nearby states; for a while it was widely employed in eastern peach orchards, but has now been supplanted by newer and more effective materials in that area.

Calcium Arsenate, $Ca_3(AsO_4)_2$, or tricalcium arsenate, is the next most popular arsenical insecticide. The commercial product is predominantly tricalcium arsenate, but it also contains acid calcium arsenate, $CaHAsO_4$, other related compounds, hydrated lime, and calcium carbonate. It is used primarily for control of cotton and truck crop insects. Although cheaper than lead arsenate, it is more likely to injure plant foliage.

Paris Green, $Cu(C_2H_3O_2)_2 \cdot 3Cu(AsO_2)_2$, or copper acetoarsenite, was

the first most widely applied arsenical insecticide. It was recommended almost exclusively in the early efforts to control Colorado potato beetles, but it serves now primarily as an ingredient of poisoned baits and as a mosquito larvicide. Being an arsenite, it is quite toxic to plant foliage as well as to animals.

Magnesium Arsenate, $Mg_3(AsO_4)_2$, also contains the acid magnesium arsenate $MgHAsO_4$. In the past this compound has been recommended extensively in control of the Mexican bean beetle since it gave effective control and did not injure bean foliage, but at present it is little used because other compounds with more favorable characteristics have taken its place.

Arsenious Oxide, As_2O_3, or white arsenic, is one of the basic materials from which the arsenites are made. It is highly toxic to plants and animals. It has served mainly as a poison for baits.

Sodium Arsenite, often a mixture of Na_3AsO_3 and $NaAsO_2$, is a water-soluble compound which has been widely used as a poison for grasshopper and ant baits, as a soil poison for termites, and as a weed eradicant.

Other Arsenicals. Manganese arsenate, basic copper arsenate, sodium arsenate, zinc arsenite, and zinc arsenate are other compounds that have been developed but now are little used as insecticides.

Fluorine Compounds. These compounds are made from calcium fluoride and cryolite and were developed as substitutes for the arsenicals. At times they had a rather wide use, especially during World War II when many other insecticides were in short supply. Today they are still utilized but are being replaced by more effective chemicals.

Sodium Fluoaluminate, Na_3AlF_6, or cryolite, is the most extensively applied fluorine insecticide. It occurs as a natural mineral in Greenland. A so-called "synthetic" cryolite is lighter and fluffier and therefore has better physical properties. Cryolite serves primarily for controlling vegetable garden pests such as Mexican bean beetle, flea beetles, tomato fruitworm, and blister beetles. It has been applied for codling moth control in northwestern United States. It has not proved satisfactory for this pest in eastern orchards but is effective for apple flea weevil control. It is not compatible with nicotine, lime-sulfur, bordeaux mixture, lime, paris green, or calcium arsenate.

Sodium Fluosilicate, Na_2SiF_6, is employed in grasshopper, cutworm, cricket, and weevil baits. Although less effective than sodium fluoride, it also substitutes in controlling lice and roaches. A water solution of it is used to mothproof fabrics against carpet beetles and clothes moth larvae.

Sodium Fluoride, NaF, is effective in controlling chewing lice, especially on poultry, and it is generally applied undiluted as a dust or used in water as a dip. It also controls roaches and ants when applied as a dust

which acts as a tracking poison. It is often recommended as the poisonous ingredient of baits for controlling cutworms, earwigs, and grasshoppers. It is phytotoxic and should not be applied to plants.

Barium Fluosilicate, $BaSiF_6$, has been used in the control of bean beetles and other garden insects. It is effective in the control of blister beetles, flea beetles, and apple flea weevils. It is considered incompatible with the same materials as were indicated for cryolite.

Mercury Compounds. These have served in controlling root maggots of cabbage, radish, and onions. The two most common compounds are corrosive sublimate or *mercuric chloride* ($HgCl_2$) and calomel or *mercurous chloride* ($HgCl$). The former is applied as a solution at the rate of 1 ounce to 10 gallons of water, and the latter as a suspension of 3 to 4 ounces per 10 gallons of water or as a dust.

Boron Compounds. The principal compounds in this group are *borax*, $Na_2B_4O_7$, and *boric acid*, H_3BO_3. Both have been used to kill house fly larvae in manure, and boric acid solution has served as a poison for roaches.

Antimony Compounds. The major compound is *potassium antimonyl tartrate*, $(KSbOC_4H_4O_6)_2 \cdot H_2O$, or tartar emetic. It is used in sweetened baits for control of some flies and moths but is more widely applied for controlling thrips on gladioli, onions, and citrus. The usual mixture is made with 4 pounds of tartar emetic, 16 pounds of brown sugar, and 100 gallons of water. *Calcium antimonyl tartrate* is a less expensive compound and is reported to be as toxic.

Thallium Compounds. These are highly poisonous materials and are combined with a sweet or fatty substance for ant baits. The common forms are *thallous sulfate*, Tl_2SO_4, and *thallous acetate*, $TlOOCCH_3$.

Phosphorus Compounds. Yellow *phosphorus* is an ingredient in roach and rat baits, and *zinc phosphide* has been used in cricket, grasshopper, and rodent baits. These are very poisonous compounds and should be handled with care.

Miscellaneous Stomach Poisons. *Formaldehyde* or *formalin* (35–40% water solution) makes a good poison for killing house flies when mixed with skim milk or sweetened water. *Sodium selenate*, Na_2SeO_4, is applied to greenhouse soil to control spider mites, aphids, and other pests of floral crops. This is an extremely poisonous material and is absorbed into the plants. It should never be applied on soils which may later be utilized for food crops.

Contact Poisons

Substances that kill insects by contact are derived from many sources and act in different ways, not all of which are thoroughly understood.

Generally it can be said that they enter either through the body wall or the respiratory system and thereby affect the nerve and respiratory centers and the blood stream. Contact poisons may be applied for controlling insects having any type of mouthpart. Many materials listed under this heading would also result in stomach poison action if taken internally through the mouth, but most of them affect the normal functioning of the insects before ingestion takes place.

Botanicals and Derivatives. Some of our most common insecticides come from plants. The seeds, flowers, leaves, stems, or roots may contain the toxic ingredients, and these are formulated for use in various ways. Although many plant poisons are quite toxic to certain insects, most of them do not leave very long-lasting residues toxic to man and other animals. This is a desirable feature for an insecticide, especially when applied to edible crops which are about to be harvested.

Nicotine, $C_{10}H_{14}N_2$, is one of the oldest materials to be used as an insecticide. It comprises the most important toxicant of a number of alkaloids found principally in the leaves and stems of the commercial species of tobacco, *Nicotiniana tabacum* and *N. rusticum.* Several other species of tobacco plants also contain nicotine alkaloids. Nicotine is sold on the market largely as 40% *nicotine sulfate.* This is diluted with water and applied as a spray. More rapid release of the nicotine results when soap, hydrated lime, or lime-sulfur is added. Powdered soap requirements are approximately 4 pounds per 100 gallons or 2 heaping teaspoonfuls per gallon of spray.

Another compound is called *free nicotine;* it may contain either 40, 50, or 95% actual nicotine. This product is highly volatile and usually kills more quickly than nicotine sulfate when used at the same dilution.

Both nicotine sulfate and free nicotine are insecticides with very short periods of insecticidal activity. To prolong this activity, nicotine sulfate has been combined with different materials to produce what are called "fixed nicotines," one common substance being bentonite. This product gives off nicotine more slowly and consequently gives longer plant protection. It has been substituted for lead arsenate in order to avoid poisonous residues on such crops as apples and grapes near harvest time.

Nicotine preparations are compatible with most insecticides and fungicides, some exceptions being cryolite, barium fluosilicate, and calcium cyanide.

Other nicotine alkaloids that have been developed but not widely used are *anabasine* and *nornicotine.*

Rotenone, $C_{23}H_{22}O_6$, is one of the principal toxic ingredients found in the roots of the leguminous plants known as derris, cubé (pronounced koo-bay), and cracca. There are other closely related compounds (rote-

noids) which also possess insecticidal properties. These should be taken into consideration when formulating. The amount of these other toxicants is usually expressed as a percentage of the total extractives, using ether, chloroform, acetone, or some other solvent as the extracting agent.

Derris plants are grown in the East Indies and nearby countries, the principal species being *Derris elliptica*, and *D. malaccensis*. Cubé plants are grown primarily in South American countries, the common species being *Lonchocarpus utilis* and *L. urucu*. Cracca is found in the United States and is known as devil's shoestring, the principal species being *Tephrosia virginiana* L. These plants are known as fish poisons because infusions of them in water paralyze fish. Derris was first applied in this way by the natives in the East Indies to obtain fish for food, the earliest reference to this being in 1665. The first record of its use as an insecticide was in 1848, when it was applied to control insects attacking nutmeg trees in Singapore.

Rotenone, or products containing it, are primarily contact poisons in their action although they have been shown to possess stomach poison properties.

Dusts are formulated to contain 0.75% or 1% rotenone, and emulsifiable concentrates for dilution with water normally contain 1% rotenone. When applied as a suspension in water, a common recommendation is 4 pounds of the finely ground root (containing 4–5% rotenone) to 100 gallons of water. Usually detergent or powdered soap is added to act as a spreading agent. The residues remain toxic to insects for three to five days, but are considered nontoxic to higher animals. Because of this property, rotenone insecticides can be applied near harvest time without danger of poisoning warm-blooded animals.

Pyrethrum insecticides come from the flowers of species of plants belonging to the genus *Chrysanthemum*, the principal commercial species being *C. cinerariaefolium* (Trev.). Pyrethrum has been known for hundreds of years for its insecticidal properties; the finely ground flowers were commonly called "insect powder." Gnadinger* states that it was first used as an insecticide in Persia. The flowers have been grown in various countries including Japan, United States, Brazil, Dalmatia in Yugoslavia, and Kenya in East Africa, the last two being the main sources of supply today. From the dried powdered flowers are extracted toxicants called "pyrethrins." In descending order of toxicity these are: pyrethrin I ($C_{21}H_{28}O_3$), cinerin I ($C_{20}H_{28}O_3$), pyrethrin II ($C_{22}H_{28}O_5$), and cinerin II ($C_{21}H_{28}O_5$). The pyrethrins are quite toxic to insects, causing rapid paralysis owing to their effect on the nervous system. Because of this paralytic

*C. B. Gnadinger, *Pyrethrum Flowers*, 2nd edition, McLaughlin Gormley King Co., Minneapolis, 1936; Supplement to 2nd edition, 1945.

action they are often combined with other toxicants to produce rapid knockdown. When dissolved in volatile oils they make excellent space sprays for fly and mosquito control. They are also valuable for controlling garden pests, especially when destructive populations are present near harvest, because the residue rapidly becomes nontoxic in the presence of air, moisture, and light. Most space sprays, aerosols, and dusts are formulated to contain from 0.1 to 0.3% pyrethrins. The emulsifiable extracts are marketed under trade names and should be diluted with water according to the manufacturer's directions. Pyrethrum insecticides are quite safe on plants and have only slight toxicity to higher animals.

A derivative of cinerin I, named *allethrin*, has been synthesized. Although less toxic than the naturally occurring toxicants in pyrethrum, it is a more stable compound. Its preparation results in a uniform product which can be more easily standardized for commercial use than the naturally occurring pyrethrum toxicants. Other synthetic derivatives of pyrethrum are *cyclethrin*, *furethrin*, *barthrin*, and *dimethrin*. They are used primarily in fly sprays.

Sabadilla. These toxicants are derived from the seeds of a number of species of plants in the lily family, a common one being *Schoenocaulon officinale*, grown commercially in Venezuela. The active materials are a complex group of alkaloids related to veratrine. From 10 to 20% dusts and 50% wettable powders are formulated from the finely ground seeds. Sabadilla has served primarily in controlling plant-feeding bugs and as a louse powder. Exposed residues on plants quickly become nontoxic. The major objection to sabadilla insecticides is the property of being highly irritating to the mucous membranes.

Ryania insecticides are made from the ground stems and roots of a South American plant, *Ryania speciosa*. These are formulated for application as dusts or suspensions in water. The toxic principles are complex alkaloids, the major one being *ryanodine*. These alkaloids are rather stable compounds and give longer residual toxic action than either pyrethrum or rotenone. The residue is less toxic to mammals than rotenone. The major use of ryania has been for control of European corn borer and sugarcane borer.

Hellebore is made of ground dried roots of plants belonging to the genus *Veratrum*, the principal species being *Veratrum album*, grown in southern Europe and Siberia. The toxicants are a group of complex alkaloids. Because of high cost and variability in toxic action, this insecticide is now little used.

Oils. The word "oil" covers a wide range of liquid chemical compounds composed primarily of carbon and hydrogen. They are lighter than water, usually greasy, and soluble in such substances as toluene, carbon disulfide,

carbon tetrachloride, chloroform, and ether. Oils may be classified into three major groups: *animal* and *vegetable* oils, *aromatic* or *essential* oils, and *petroleum* oils. Some examples of oils of animal origin are whale, fish, and neat's-foot oils; those of vegetable origin are soybean, castor, cottonseed, linseed, peanut, palm, corn, safflower, and olive oils. They all saponify easily with alkalies, and are little used as insecticides except in the form of soaps. Wintergreen, peppermint, citronella, camphor, eugenol, geraniol, and menthol are examples of aromatic oils. They are volatile, do not saponify in the presence of alkalies, and are not greasy. Citronella is applied as a mosquito repellent, and geraniol and eugenol are Japanese beetle attractants. The petroleum oils are of mineral origin and are derived from sedimentary rocks. They comprise the most important group from the standpoint of insect control and are especially effective as contact insecticides for all insect life stages. Petroleum oils also serve as carriers for toxicants and often increase their effectiveness. Some products separated by fractional distillation and purification of crude petroleum, in order of volatility, are: naphtha, gasoline, benzene, kerosene, fuel oil, lubricating oils, petrolatum, paraffin wax, asphalt, tar, and pitch.

In order to understand the use of petroleum oils as insecticides certain specifications as to their properties should be considered. These specifications are based on viscosity, volatility, and degree of refinement.

Viscosity is defined as resistance to flowing and is measured by the Saybolt test, which is the number of seconds required for 60 cubic centimeters to flow through a standard opening at 100° F. Dormant spray oils have a Saybolt reading of 90–150 seconds and a summer spray oil of 45–85 seconds. Oils of low viscosity are safer on plant foliage.

Volatility is measured by the boiling points of the fractions as distilled. A light oil has a boiling point range of 160°–300° F., a medium oil of 300°–575° F., and a heavy oil from 575° F. upward.

Degree of refinement means the purity of the oil. Certain unsaturated hydrocarbons are present in oils, and these are removed by treatment with sulfuric acid. If such treatment does not remove any portion of the oil it would be 100% unsulfonatable (or have 100% purity). Dormant oils range from 65 to 85% in unsulfonatable residues for the "regular" type, and from 90 to 92% for the "superior" type. Most summer spray oils range from 90 to 98% in unsulfonatable residues.

Naphtha, gasoline, and benzene are little used as insecticides or solvents for insecticides because of their high volatility and flammability. Various grades of kerosene serve as solvents for toxicants in livestock fly sprays, household insecticides, and mosquito larvicides. At one time kerosene-type oils were employed extensively for field spraying, but more recently oils having greater viscosity and lower volatility have been substituted.

Oils are injurious to plants when applied undiluted. Since they are insoluble in water they must first be made into "emulsions." This is done by mixing an emulsifier with the oil and water so that the droplets of oil remain uniformly suspended in the water until applied to the plant. There is a wide variety of substances suitable as emulsifiers, several of which will be mentioned in a later discussion. Miscible oils are solutions of oil and the emulsifier with certain other materials which make rapid emulsification possible when water is added. They contain very little if any water and therefore are not affected by freezing temperatures. They are recommended primarily for dormant use at strengths of 2 to 5% oil for controlling scale insects and the eggs of aphids and spider mites.

Tank-mix oils are prepared as emulsions just before application. The oil is added to the emulsifier and water in the spray tank with the pump and agitator in operation. Pumping is continued until all the oil is emulsified. Commercial-stock oil emulsions of various types are available which contain 80–90% oil, the remaining portion being water and emulsifier. They emulsify readily when mixed with water for spraying. Some have the consistency and appearance of mayonnaise, others are light-colored, highly refined oils called "white" or "summer" oil emulsions. The white oil emulsions are diluted with water so that the final spray contains from 1 to 2% oil. These and coal-tar oil emulsions, kerosene emulsions, and distillate oil emulsions can be purchased commercially, already emulsified for dilution with water. These standard products are preferable to amateur preparations, and it is wise to follow the directions of the manufacturer since the oil content of each one varies. To avoid plant injury oil sprays must be thoroughly emulsified and should not be applied in freezing weather or on oil-sensitive plants.

Dinitrophenyl Compounds. The sodium salt of *4,6-dinitro-o-cresol* is sold under the trade names of Elgetol 30 and Sinox. These products are used in dormant oil sprays as ovicides for mite and aphid eggs, as blossom-thinning sprays on fruits, and as weed killers. A related compound, *4,6-dinitro-o-cyclohexylphenol,* has been employed primarily for spider mite control. Trade names for this compound are DN-111 and DN-Dry Mix No. 1. A chemical for strictly dormant application is the triethanolamine salt of *4,6-dinitro-o-sec-butylphenol,* known commercially as DN-289, or Elgetol 318. Follow directions specifically to avoid plant injury. Other DN compounds having acaricidal properties are Karathane, or *dinitro(1-methylheptyl) phenyl crotonate,* and binapacryl, or *2-sec-butyl-4,6-dinitrophenyl-3-methyl-2-butenoate.* Louse powders containing *2,4-dinitro-anisole* as an ovicide were developed during World War II. The ingredient is also present in some commercial preparations for controlling roaches, poultry lice, and bed bugs.

Thiocyanates. *Lauryl thiocyanate*, marketed under the trade name Loro, is toxic to such pests as mealybugs, scales, aphids, thrips, whiteflies, and spider mites; it has been used in both the greenhouse and the field. *Beta-butoxy-beta-thiocyanodiethylether*, marketed as Lethane 384, and *isobornyl thiocyanoacetate*, marketed as Thanite, are ingredients in many commercial fly sprays. For safety to plants as well as to the person applying the chemicals, the manufacturer's directions should be carefully followed.

Sulfur Compounds. These have been used for controlling spider mites, chiggers, many true bugs, some leafhoppers, and livestock parasites, as well as for fungicide purposes. One of the most valuable qualities seems to be a residual effect on insects, continuing for several days after the application of the material. *Dusting sulfur* may be applied alone or as a diluent for other toxicants. *Wettable sulfurs* mix directly with water for application as sprays because a wetting agent has been added for that purpose. *Colloidal sulfurs* are made by special processes that result in smaller particles than are obtained by grinding. *Flotation sulfur* is of extremely fine particle size, approaching that of colloidal sulfur. It is a byproduct of the manufacture of fuel gas from coal and is more active than flowers of sulfur. *Lime-sulfur* is a mixture of polysulfides of calcium and was the standard treatment for scale insect control for many years before its replacement by oil sprays. It is still extensively applied as a fungicide for orchards, and at summer strength for controlling scale insects and mites. Most commercial liquid lime-sulfurs are standardized at 33° on the Baumé scale. For dormant use they should be diluted, 1 part to 8 parts water, and for summer use, 1 to 40 or 50 parts of water. *Dry lime-sulfur* is liquid lime-sulfur which has the water removed. Four pounds of dry lime-sulfur is equivalent to 1 gallon of liquid lime-sulfur. This should be kept in mind when substituting one form for the other. Lime-sulfur should be used carefully near buildings, for it will cause discoloration of the paint.

Phenothiazine. This is a sulfur-containing heterocyclic compound having the formula $C_{12}H_9NS$. In combination with lead arsenate it has been shown to be very effective for codling moth control. It is used primarily as an anthelmintic for domestic animals.

Chlorinated Compounds. Practically all the chemicals to be discussed here were made and developed as insecticides during and after World War II. Many of them give phenomenal control compared to those in use before this period; because of this, some insect pests are no longer considered difficult problems to cope with; others for which we had had no control have now been successfully checked. However, occasionally certain of these chemicals has also favored the development of some pests. Most of these

compounds have persistent, toxic residues. This property has been described as *residual action.* Although primarily contact poisons, they also are toxic if taken into the alimentary canal, and many possess poisonous vapors. Precautionary measures should be exercised in handling all the chemicals listed in this category.

DDT, $C_{14}H_9Cl_5$, or dichlorodiphenyltrichloroethane, was first synthesized in Germany in 1874, but it was not until 1942 that samples and factual knowledge of its insecticidal properties were received in the United States. Since then it has been widely tested and accepted as an outstanding insecticide. Chemically it is a complex mixture of isomers, of which about 77% is the para-para isomer. There are three grades of DDT: "technical" which has a setting point of about 93° C., "purified" or "aerosol" having a setting point of 103° C., and "chemically pure" para-para isomer with a setting point of about 109° C. The technical grade is the cheapest and most popular; the purified or aerosol grade is utilized in aerosols and on tomato, cucumber, squash, melon, pumpkin, and other plants injured by the technical grade. In oil solutions, DDT is readily absorbed through the skin of animals and is accumulated in the fatty tissues. Long exposures to such formulations should be avoided. Residues of DDT in buildings may remain toxic for as long as 12 or more months, whereas outdoor applications, exposed to sunlight and weathering, become ineffective in 30 days or less. DDT on plants favors the development of spider mites, certain scales, aphids, and some leaf roller populations; this is often due to the killing of the natural enemies of these pests without killing the pests in question. It is an effective insecticide for a wide range of insects.

TDE, $C_{14}H_{10}Cl_4$ (also called DDD), or dichlorodiphenyldichloroethane, is an analogue of DDT in which it is present as an impurity. Although not as toxic to most insects and to warm-blooded animals, it has proved to be better than DDT for controlling red-banded leaf roller, tomato and tobacco horn worms, and some mosquito larvae.

Methoxychlor, $C_{16}H_{15}Cl_3O_2$, is the accepted name for the *p-methoxyphenyl* analogue of DDT. It is less toxic than DDT to warm-blooded animals, does not accumulate as rapidly in animal fat, and can be applied with safety to tomato and cucurbit plants. It is effective for controlling a wide variety of insects on fruits, vegetables, forage crops, and livestock.

Perthane, $C_{18}H_{20}Cl_2$, is the *p-ethylphenyl* analogue of DDT. It has a very low acute and chronic mammalian toxicity and is useful primarily as a household insecticide alone or in combination with other chemicals.

Dilan is a mixture of 1 part of *2-nitro-1, 1-bis (p-chlorophenyl) propane* (called Prolan) and 2 parts of *2-nitro-1, 1-bis (p-chlorophenyl) butane* (called Bulan). The mixture is much less toxic than DDT to warm-blooded

animals and it has proved to be more effective than DDT in controlling some insects.

Dimite, or DMC, chemically *di(p-chlorophenyl) methyl carbinol*, is a miticide with long residual action, effective for controlling most mite species on plants and with low toxicity to mammals.

Chlorobenzilate, $C_{16}H_{14}Cl_2O_3$, or *ethyl 4,4′-dichlorobenzilate*, is a miticide highly toxic to a number of species, especially the two-spotted strains showing resistance to parathion. It is compatible with a wide range of common insecticides and fungicides, but highly alkaline materials retard its action.

Kelthane or *1,1-bis(p-chlorophenyl)-2,2,2-trichloroethanol* is an effective miticide for a wide range of species and those showing resistance to the organo-phosphorus compounds. It has rapid initial killing action and a long-lasting residue of moderate to low mammalian toxicity.

Benzene Hexachloride or BHC, $C_6H_6Cl_6$, was first made by Faraday in 1825, but its insecticidal properties were not discovered until 1941. From the crude odoriferous material five isomers have been isolated, the one most toxic being the gamma isomer. An almost odorless product containing 99% or more pure gamma isomer is called *lindane*. Benzene hexachloride is more volatile than DDT and exposed residues only last several days in sunlight and high temperature. Inside buildings or in soils it persists for many months. The odor of the crude product is persistent and objectionable, and it is absorbed by vegetable and fruit crops making them unpalatable. For this reason care must be exercised when using this material in order to avoid contaminating edible crops. Lindane has partly overcome this disagreeable characteristic and is the only form in which benzene hexachloride is now applied in household insect control. The product is effective in controlling grasshoppers, spittlebug nymphs, aphids, chiggers, plant bugs, mange mites, flies, thrips, and many other pests.

Chlordane, $C_{10}H_6Cl_8$, consists of a light amber viscous liquid containing a number of related chemical compounds, readily soluble in most organic solvents but insoluble in water. It is more toxic and more volatile than DDT and possesses both residual and vapor toxic action properties. In the presence of alkalies, chlordane becomes nontoxic. It is highly effective for controlling soil insects such as termites, ants, wireworms, white grubs, sod webworms, root maggots, Japanese beetle grubs, and clover root borers. Other pests which it also controls are flies, mosquitoes, roaches, carpet beetles, clothes moths, fleas, chiggers, grasshoppers, thrips, plant bugs, leaf miners, and sweet clover weevils.

Heptachlor, $C_{10}H_5Cl_7$, is an ingredient in technical chlordane. Because it is more volatile exposed residues are not as persistent, but over a period

of time they gradually change to heptachlor epoxide, a more toxic and persistent residue compound. Heptachlor is more toxic than chlordane or DDT and is stable in alkalies and acids. It is widely recommended for controlling termites, ants, grasshoppers, and various soils insects.

Aldrin, $C_{12}H_8Cl_6$, in pure form is a white crystalline substance with about the same toxicity and volatility as heptachlor. Stable in alkalies and compatible with most fungicides and insecticides, it like heptachlor kills many pests. Because of its high toxicity, approval for its use has been limited primarily to control grasshoppers, cotton and soil insects. Over a period of time aldrin gradually changes to its epoxide dieldrin, a much more toxic and persistent residue compound. A stereoisomer of aldrin, named isodrin, also possesses high toxicity to a number of insects.

Dieldrin, $C_{12}H_8Cl_6O$, has properties similar to heptachlor and aldrin, except that it has higher toxicity and the residue persists longer, the duration being about the same as DDT. Research data indicate it to be more toxic to most of the insects listed for chlordane, but because of its higher toxicity approved uses are limited to a few crops such as cotton where its toxic residues are not a problem. A highly toxic stereoisomer, named endrin, is commercially available but persistent hazardous residues also limit its use.

Toxaphene, $C_{10}H_{10}Cl_8$, is a chlorinated camphene compound consisting of a mixture of isomers, the technical material having the appearance of gummy brown sugar. It is unstable in the presence of alkalies and with prolonged exposures to sunlight or high temperatures, and is less toxic than DDT to most insects. The common uses are for controlling cotton insects, grasshoppers, and spittlebug nymphs.

Strobane is a chlorination product of camphenes and related terpenes containing 66% chlorine. The exact chemical structure has not been determined. It is recommended primarily for control of cotton insects.

Kepone, $C_{10}Cl_{10}O$, has not been thoroughly tested for insecticidal properties. It is a promising compound in baits for controlling ants, cockroaches, and some soil insects. It is registered for application to potatoes and ornamental plants.

Mirex, $C_{10}Cl_{12}$, is an aromatic chlorinated hydrocarbon compound recommended for controlling the imported fire ant. It is registered for use on ornamental plants and some field crops. It has low mammalian toxicity.

Endosulfan, $C_9H_6Cl_6O_3S$, is both a miticide and an insecticide. It is very effective in controlling aphids, spittlebugs, whiteflies, and leafhoppers and is approved for use on certain fruit and vegetable crops. It is also known as Thiodan.

Telodrin, $C_9H_4Cl_8O$, is a highly toxic hydrocarbon compound that is

still in the experimental stage of development. Its acute oral LD_{50} for rats is 4.8 mg/kg.

Pentac or *bis (pentachloro-2,4-cyclopentadien-1-yl)*, is a miticidal chemical manufactured by the Hooker Chemical Company. It has been used primarily on floral and nursery crops.

Pentachlorophenol, C_6Cl_5OH, is a flaky crystalline solid that is dissolved in oil solvents to the extent of 5% and marketed as a wood preservative and termite-proofing material.

Sulfonate, Sulfone, Sulfide, and Sulfite Compounds. Most of the chemicals in this group are effective only as miticides. A few have properties for permanently mothproofing wool.

Ovex, or *p-chlorophenyl p-chlorobenzenesulfonate*, is highly effective in killing spider mite eggs and resting stages. It is also useful in ridding laboratory animals and roach cultures of ectoparasitic mites.

Genite, or *2,4-dichlorophenyl benzenesulfonate*, is an analogue of ovex and has similar miticidal properties.

Fenson, or *p-chlorophenyl benzenesulfonate*, is another analogue of ovex with similar miticidal properties.

Sulphenone is the trade name of a miticide containing 70% *p-chlorophenyl phenyl sulfone* plus 30% related sulfones.

Tetradifon, or *p-chlorophenyl 2,4,5-trichlorophenyl sulfone*, is a slow-acting but effective miticide. At the proper dosage it will kill small crawling stages and cause adult females to deposit sterile eggs. Two applications a week apart are usually necessary for control. It has little effect on beneficial insects. This chemical is also known as Tedion.

Chlorbenside, or *p-chlorobenzyl p-chlorophenyl sulfide*, is a widely used miticide. It has very low mammalian toxicity and its residues are not considered hazardous.

Fluorbenside, or *p-chlorobenzyl p-fluorophenyl sulfide*, is chemically the same as chlorbenside except that fluorine has been substituted for chlorine in the molecule. It is miticidal in action and over three times more toxic to warm-blooded animals than chlorbenside.

Aramite, or *2(p-tert-butylphenoxy)isopropyl-2-chlorethyl sulfite*, is an effective miticide with low mammalian toxicity but shown to possess carcinogenic properties to mice. It is recommended for use only on cotton and ornamental plants.

Mitin FF and Eulan CN are two widely used sulfonate compounds that are mixed with the dye bath and react with the protein molecule to permanently mothproof wool.

Carbamate Compounds. This group of insecticide chemicals became popular with the relatively low mammalian toxicity and broad-spectrum

characteristics of carbaryl or Sevin. Carbamates are inhibitors of cholinesterase enzymes, and atropine is the antidote. The carbamates are unstable in alkaline mixtures.

Carbaryl, or *1-naphthyl N-methylcarbamate,* is now recommended for control of a wide range of insect pests. It is not considered effective against phytophagous mites. Occasionally it is phytotoxic to some hosts. Because of its relatively nontoxic residue, it is approved for use on edible crops close to harvest.

Zectran, or *4-dimethylamino-3,5-xylyl methylcarbamate,* is effective in killing a wide range of pests on turf, trees, flowers, and shrubs.

Other carbamate insecticides are the following: *dimetilan* is registered for house fly control in dairy barns and other buildings using baited bands; *Isolan* is effective in aphid control by systemic action and it is also useful in fly baits; *Pyrolan* has replaced parathion in methyl eugenol baits for control of oriental fruit fly; *dimetan* is toxic to some mites and is a promising aphicide; and *Baygon* shows promise for controlling public health and ornamental plant pests.

Organophosphorus Compounds. Some of this group of compounds were discovered in chemical laboratories in Germany near the end of World War II, and have since been developed as insecticides. They possess an extremely high order of toxicity to insects and mites as well as to other forms of animal life. The respiratory tract, eyes, and skin must be protected during their application, as they are toxic if swallowed, inhaled, or absorbed through the skin. They are cholinesterase inhibitors, and therefore the symptoms of poisoning are those of marked parasympathetic stimulation. Nausea, vomiting, diarrhea, cramps, blurred vision, feeling of pressure under the breast bone, sweating, excessive salivation, headache, and muscular tremors are indications. If any of these symptoms develop during application of the compounds, operations should be discontinued at once and a physician consulted. Atropine sulfate is the antidote, 2 tablets (each 1/100 grain) given immediately, followed by additional doses every hour until the pupils of the eyes dilate. Up to 0.3 grain per day may be given, if needed, to control respiratory symptoms. The acute condition lasts 24 to 48 hours, during which the patient must be under continuous observation. Some common chemicals are discussed briefly.

Hexaethyl Tetraphosphate, or HETP, is an amber, oily liquid containing a mixture of ethyl polyphosphates, the principal one being tetraethyl pyrophosphate, commercial preparations containing 10 to 20%. HETP is readily miscible with water in which it rapidly hydrolyzes to nontoxic residues. Because of this property it can be applied to eliminate insect or mite populations on edible crops near harvest. When mixed with water it should be applied immediately.

Tetraethyl Pyrophosphate, or TEPP, as already pointed out, is the major toxicant in HETP and hence has similar properties. Most commercial preparations contain 40% TEPP, along with other polyphosphates, but, since the content varies with different commercial products, it is best to follow the directions of the manufacturer. TEPP is also readily miscible with water and hydrolyzes to nontoxic substances quite rapidly. This material is most widely used to control spider mites, aphids, whiteflies, thrips, and mealybugs. Only the active stages are affected.

Tetraethyl Dithiopyrophosphate is related to TEPP and has been used primarily in aerosol form for greenhouse insect control. It is more stable, hydrolyzing only in alkaline solutions, and is less toxic than TEPP to warm-blooded animals. Sulfotepp is a common name.

Parathion, or *O, O-diethyl-O-p-nitrophenyl phosphorothioate,* is a brown liquid with a garlic-like odor, resistant to aqueous hydrolysis, with a rather persistent residue which disappears sufficiently in about 20 days to make it safe for application to edible plants. This chemical has very high mammalian toxicity and should not be applied for livestock or household pest control. It is especially effective for controlling insects and mites attacking ornamental plants, greenhouse, fruit, vegetable and field crops. It is compatible with lead arsenate, neutral copper fungicides, chlorinated hydrocarbons, and elemental sulfur. The methyl analogue of parathion is called *methyl parathion.* It is almost as widely used as parathion. It hydrolyzes more easily, is less stable in storage, and the residue is not as persistent, but it has almost the same mammalian toxicity. *Dicapthon* and *chlorthion* are chlorinated analogues of methyl parathion. They are much less toxic to mammals and are therefore useful where high toxicity is hazardous. Dicapthon is safe to use as a household insecticide in controlling German cockroaches resistant to chlorinated compounds.

Metacide is a product consisting of $\frac{3}{4}$ of the dimethyl analogue of parathion mixed with $\frac{1}{4}$ of parathion. It is supposed to be less toxic than parathion, but there is actually little difference in mammalian toxicity. It is used to control about the same pests as indicated for parathion, but sometimes a larger dosage is required. This is especially true for controlling spider mites.

EPN, or *O-ethyl O-p-nitrophenyl phenylphosphonothioate,* has a wide range of effectiveness for mite and insect control. Perhaps the greatest usage is in controlling tree fruit pests and some rice and corn insects. It is less toxic to mammals then parathion and is compatible with lime-sulfur, wettable and paste sulfurs, nicotine, lindane, DDT, and the dithiocarbamates.

Malathion, or *O, O-dimethyl dithiophosphate of diethyl mercaptosuccinate,* has a very low mammalian toxicity and is considered one of the

safest organo-phosphorus insecticides. It is widely recommended for controlling many mite and insect species. At least two or more applications are required for successful control. It has an unpleasant odor but this has been solved to some extent by making a premium grade for use around human habitation by pest control operators. Malathion is useful in controlling German cockroaches that have developed resistance to the chlorinated hydrocarbon insecticides.

Diazinon, or *O, O-diethyl O-(2-isopropyl-6-methyl-4 pyrimidyl) thiophosphate*, is a broad spectrum insecticide with good residual action and moderate toxicity to mammals. It is effective against house flies, corn rootworms, and German cockroaches that become resistant to the chlorinated hydrocarbons.

Guthion, or *O, O-dimethyl S-4-oxo-1,2,3-benzotriazin-3(4H)ylmethyl phosphorodithioate*, is a highly toxic compound with a wide range of effectiveness in controlling mites and insects. It is almost as toxic as parathion to warm-blooded animals. *Ethylguthion* is an analogue of guthion with a slightly higher mammalian toxicity. It kills the same pests as guthion.

Trithion, or *S-(p-chlorophenylthiomethyl) O, O-diethyl phosphorodithioate*, has a persistent residue and is quite toxic to mammals. It is used primarily for controlling insects and mites on pome fruits and some vegetables. An approved common name is carbophenothion. The methyl analogue is known as *methyl trithion*.

Delnav, or *2,3-p-dioxanedithiol S, S-bis(O, O-diethyl phosphorodithioate)*, is active as a miticide and as an insecticide. Its residues are rather persistent and its mammalian toxicity is moderate. Various fruit crop pests are controlled with this compound which has the common name of dioxathion.

Ethion, or *O,O,O′, O′-tetraethyl S, S′-methylene bisphosphorodithoate*, has moderate mammalian toxicity and gives effective control of mites and insects on pome fruits, citrus fruits, and some vegetable crops.

Ciodrin, or *a-methylbenzyl-3-(dimethoxyphosphinyloxy)-cis-crotonate*, is highly effective in controlling livestock pests. It is moderately toxic to warm-blooded animals.

Dipterex, or *dimethyl (2,2,2-trichloro-1-hydroxethyl) phosphonate*, is a water soluble compound with a relatively low mammalian toxicity. It is useful in ridding horses of bots, in fly baits, and in controlling many pests on field crops and ornamentals. Above pH 6 Dipterex in solution is rapidly converted to DDVP. It has a common name of trichlorfon.

DDVP, or *O, O-dimethyl 2,2-dichlorovinyl phosphate*, has a fairly high mammalian toxicity but is highly volatile and useful as a knockdown agent in aerosols. It is effective as a bait in controlling house and face flies. The compound has a short life residue. Another name for it is dichlorvos.

Dibrom, or *1,2-dibromo-2,2-dichloroethyl dimethyl phosphate*, is bromi-

nated DDVP. It has a rather low mammalian toxicity and a rather short residual life. It is recommended for controlling many pests in greenhouses by applying it to the heating pipes. The lack of a persistent residue makes it safe to use on various agricultural crops near harvest time. A common name for the chemical is naled.

Abate, or *O,O,O′, O′-tetramethyl O, O′-thiodi-p-phenylene phosphorothioate,* is highly effective as a mosquito larvicide. Its relatively low mammalian toxicity (acute oral LD_{50} to male rats is 1000 mg/kg of body weight) makes it a promising compound to use without appreciable effect to wildlife.

Dursban, or *O, O-diethyl O-3,5,6-trichloro-2-pyridyl phosphorothioate,* is a promising chemical for controlling chinch bugs and sod webworms in lawns. Its mammalian toxicity is favorable for such usage; the acute oral LD_{50} to male rats is 163 mg/kg of body weight.

Baytex, or *O, O-dimethyl O-[4-(methylthio)-m-tolyl] phosphorothioate,* has moderate mammalian toxicity and is useful in controlling livestock pests, insects and mites on grains, forage, fruits, vegetables, and ornamentals, as well as mosquitoes. It has a common name of fenthion.

Imidan, or *O, O-dimethyl S-phthalimidomethyl phosphorodithioate,* is registered for controlling mites and insects on some crops and cattle, but it is known especially as an insecticide for cotton boll weevil.

Azodrin, $PNO_5C_7H_{14}$, or *dimethyl phosphate of 3-hydroxyl-N-methyl-cis-crotonamide,* is a highly toxic water soluble, liquid insecticide possessing systemic activity to some insect species. It is effective and approved for use against some cotton insects that have developed resistance to chlorinated hydrocarbon insecticides.

Bidrin, or *3-(dimethoxyphosphinyloxy)-N, N-dimethyl-cis-crotonamide,* is a highly toxic water soluble systemic compound approved for insect control on certain seed crops, some trees, and on cotton.

V-C-13, or *O, O-diethyl O-(2,4-dichlorophenyl) phosphorothioate,* is an insecticide, miticide, and nematicide of moderate toxicity to mammals. It is useful in controlling pests in turf, ornamentals, and potted plants.

Zytron, or *O-2,4-dichlorophenyl O-methylisopropylphosphoramidothioate,* has moderate mammalian toxicity and is useful in controlling chinch bugs in lawns.

Ronnel, or *O, O-dimethyl O-(2,4,5-trichlorophenyl) phosphorothioate,* has a mild mercaptan odor and very low mammalian toxicity. It is employed as an oral systemic insecticide in cattle for control of grubs and ectoparasites and it has wide usage in eliminating other livestock and small animal pests as well as many household insects.

Ruelene, or *O-4-tert-butyl-2-chlorophenyl O-methyl methylphosphoramidate,* is an animal systemic insecticide almost twice as toxic as ronnel. It

is registered as a pour-on treatment for cattle grubs and as a beef cattle feed additive for controlling face fly maggots.

Co-Ral, or *O, O-diethyl O-(3-chloro-4-methyl-2-oxo-2H-1-benzopyran-7-yl) phosphorothioate,* has a rather high mammalian toxicity. It is a systemic insecticide for controlling many livestock pests, but it is only applied externally. It has the common name of coumaphos.

Demeton is a mixture of *O, O-diethyl S-(and O) 2-(ethylthio) ethyl phosphorothioates.* It is highly toxic to warm-blooded animals and systemic in plants, entering through the roots, leaves, or stems. It is approved for controlling insects and mites on some tree fruits, some vegetable crops, and on ornamental trees, shrubs, and flowers. The trade name for demeton is Systox and the methyl analogue of it is known as *methyl demeton* or Meta-Systox-R. It has slightly lower mammalian toxicity and is used for controlling the same pests as demeton.

Dimethoate, or *O, O-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate,* has about the same mammalian toxicity as DDT. It is systemic in plants and animals. Although commonly used as a residual spray for house fly control, it is also registered for use on some vegetables, a few other crops, and ornamentals. A trade name of dimethoate is Cygon.

Thimet, or *O, O-diethyl S-ethylthiomethyl phosphorodithioate,* has very high mammalian toxicity, is systemic in plants, and gives long protection from insect and mite attacks by applying it to the seeds at planting time, or as a side dressing at planting or transplanting. The common name is phorate.

Di-Syston, or *O, O-diethyl S-2-(ethylthio) ethyl phosphorodithioate,* is systemic in plants, has very high mammalian toxicity, and is effective in controlling mites and insects by applying it as given for phorate.

Phosdrin, or *2-methoxycarbonyl-1-methylvinyl dimethyl phosphate,* has very high mammalian toxicity, a short life residue, very toxic vapors, and is systemic in plants. Both mites and insects are killed by it. Because of its rapid volatilization and residue decomposition application can be made to edible crops close to harvest. The common name for Phosdrin is mevinphos.

Phosphamidon, or *2 chloro-2-diethylcarbamoyl-1-methylvinyl dimethyl phosphate,* is a highly toxic short life plant systemic. It is approved for use against a wide range of crop pests. Another name for it is Dimecron.

Schradan, or *octamethylpyrophosphoramide,* is also systemic in plants. It has high mammalian toxicity and persists in plants, giving good protection to ornamentals from aphid and mite attacks without harming predators and parasites.

Wetting, Spreading, Emulsifying, Adhesive, and Synergistic Agents. Combined with other toxicants, these materials insure better coverage of the sprayed surface by reducing surface tension, assist in holding the toxi-

cant to the surface, serve as formulating agents (emulsifiers), and increase effectiveness of insecticides generally. Many of them, if used alone and in concentrated form, will kill insects primarily by contact action. Wetting and spreading agents are usually not good adhesive materials and often reduce the deposit of toxicant. Most oily substances increase spray deposit.

Soaps are salts of the higher fatty acids, prepared by treating animal or vegetable fats and oils with soluble alkalies such as potassium or sodium hydroxides. Excellent as wetting, spreading, and emulsifying agents, they should not be used with alkaline water, since hard water containing calcium and magnesium salts precipitate them. In concentrated solutions they are definitely insecticidal especially to such insects as aphids. Some common examples are potash fish oil soap and commercial soap flakes and powders.

Saponins are glucoside extracts from several species of plants, especially soapwort. They foam readily in water and reduce surface tension greatly; hence they are good spreading agents.

Gelatine is a protein preparation of animal origin. Glue is an impure form of gelatine which has been recommended as an adhesive agent in sprays for spider mites.

Casein is an ingredient of skim, dried, or condensed milk, and has been employed in sprays as a spreader and an adhesive agent. Commercial casein spreaders are mixtures of casein and hydrated lime.

Detergents are an important group of chemicals that reduce surface tension in hard or soft water and have excellent emulsifying properties. They may be milled with insecticidal dusts to make wettable powders, that readily disperse into water suspensions. Commercial products such as Dreft, Tide, Tergitol, and Dupanol are examples of the sodium alkyl sulfates, and Vatsol, Ultrawet, and Nekal are examples of sodium alkyl sulfonates. The sodium alkyl aryl sulfonates are represented by Santomerse, Aresket, Nacconol, Breeze, and Fab. When employed as spreading agents, usually only 4 to 8 ounces are required per 100 gallons of spray. Closely related products are the Tritons, said to be sulfonated ethers and alcohols. The esters, formed by reacting fatty acids with the hexahydric alcohols, sorbitol and mannitol, are excellent emulsifying and wetting agents and possess considerable insecticidal activity as well. An example is NNO, the trade name for mannitan monolaurate. The "Spans" and "Tweens" are related products.

Miscellaneous Materials, such as blood albumen, starch, wheat flour, soybean flour, molasses, dextrins, rosin residues, gum karaya, gum arabic, pine oil, bentonite, clay, and polyethylene polysulfide are other substances that have been employed as wetting, adhesive, and emulsifying agents.

Synergists. Synergism, when applied to insecticides, is usually defined as

joint action of two materials so that the total toxic effect is greater than the sum of their toxic effects when applied alone. Because this joint action usually is not known, the term "activator" has been suggested as a better term. Most materials having this property were developed in trying to prolong the toxicity of pyrethrum insecticides. Some of the promising synergists or activators are the following: piperonyl butoxide, piperonyl cyclonene, sesamin, sesamex, sesmolin, sulfoxide, propyl isome, MGK 264, and the WARF antiresistant compound, *N, N-di-n-butyl-p-chlorobenzene-sulfonamide*. When the last named compound is mixed with DDT, it counteracts the resistance of insects to DDT alone. Any materials that possess the properties indicated could be placed in this category.

Dust Diluents. Large amounts of relatively inert materials serve as diluting agents or carriers in the preparation of insecticides to be applied as dusts. Since some of these have insecticidal properties,[*] they can be classified with contact poisons. Important properties to be considered in the selection of a diluent are; compatibility, *p*H, cost, stability, particle size, insecticidal activity, availability, absorptivity, abrasive action, and adhesiveness. Alkaline materials, like hydrated lime, are used in nicotine dusts to liberate the nicotine but should not be combined with DDT, methoxychlor, DDD, chlordane, BHC, pyrethrum, or rotenone because their active principles are unstable in the presence of alkalies. Pyrethrum marc, tobacco dust, and sulfur are diluents having considerable insecticidal activity to some insects and mites. Watkins and Norton[†] have classified insecticide diluents into two groups, botanicals and minerals. Examples of botanical diluents are the following: wheat and soybean flours, tobacco dust, pyrethrum marc, and walnut shell flour. The mineral group includes such compounds as calcium carbonate, magnesium carbonate, gypsum, kaolin, sulfur, bentonite, pyrophyllite, diatomaceous earth, hydrated lime, talc, attapulgite, and silica aerogel.

Fumigants

Fumigants are chemicals employed in gaseous form for killing insects or related pests, and are adapted primarily for use in enclosed spaces. Buildings to be fumigated should be thoroughly sealed. Rapid and effective penetration of a fumigant results when liberated in a tight chamber under partial vacuum. This is called *vacuum fumigation* and is employed by quarantine officers to insure imported products being insect-free. Nursery stock, foods, and many products of commerce are also treated in this manner. Fumigants may be applied in the open for controlling insects on vegetation, but in such situations more effective results are secured if the

[*] *J. Econ. Ent.*, 40:215–219, 1947.
[†] *J. Econ. Ent.*, 40:211–214, 1947.

gases are confined, even for a very short period of time. This is done by employing gastight tents, covers, or hoods. Citrus trees are fumigated while enclosed in tents; tarpaulins or covers confine soil fumigants, and long trailing hoods are employed on field crop-spraying and -dusting equipment.

The choice of a fumigant depends on several factors. These are the following: cost of material and application, toxicity to insects, safety to the operator, possibility of fire hazard, plant and animal toxicity, possible bleaching effects to household items, tarnishing effects to metals, ease of application, penetration power, persistence and effects on materials to be treated, such as the germination of seeds, milling or baking properties of flour, tainting or preserving qualities of foods. Regardless of the fumigant chosen, its characteristics should be thoroughly understood, and all necessary precautionary measures taken to safeguard human life. A brief discussion of some common fumigant materials follows.

***Hydrocyanic Acid Gas*, HCN**, or hydrogen cyanide, is the most popular fumigant, probably because it more nearly approaches the characteristics of the ideal fumigant. Extremely poisonous to animals, its action affects the respiratory organs and nerve centers. When the doses are large and exposures long it also kills plants. Although one of the most deadly poisons known it can be safely applied when proper precautions are taken. The gas is lighter than air, has a faint odor of almonds or peach stones, and has fairly good penetrating properties, but it is soluble in water, forming an acid which will react with metal. HCN has been widely utilized for the fumigation of greenhouses, grain mills and elevators, ships, storage warehouses, citrus trees, and dwellings, but, since the advent of DDT and other new compounds with residual toxicity, its popularity has decreased.

One of the earlier methods* of generating the gas was to put sodium cyanide, weighed in paper bags, into earthenware jars containing dilute commercial sulfuric acid. This was known as the "pot method." Because of the extra work involved in preparation and clean-up afterwards, most greenhouse and pest control operators do not favor this method; they prefer calcium cyanide (Cyanogas) from which HCN is liberated by its action with atmospheric moisture. For dwellings, pest control operators utilize the packaged fiber disks or discoids on which the HCN is absorbed but quickly released on exposure to air. Liquid hydrogen cyanide in steel cylinders serves in mills and warehouses, where the gas can be piped to various parts of the building for periodic fumigation. A special machine built to generate HCN from sulfuric acid and sodium cyanide has also been developed for fumigating mills, warehouses, and citrus trees.†

Methyl Bromide, CH_3Br, has become one of the most common fumi-

* *U.S.D.A. Farmers' Bull.* 1670, 1932.
† *U.S.D.A. Farmers' Bull.* 1321, 1923.

gants. It boils at 4.5° C. and is therefore practical for low temperature fumigations. It is a non-flammable gas, over three times as heavy as air, with good penetrating properties, making it particularly useful for fumigation of stored products. It has also proved efficient for fumigating tubers, corms, bulbs, balled nursery stock, flour, soil pests, lumber, greenhouses, and for delousing clothing. Methyl bromide is toxic to both insects and warm-blooded animals, and, although slow in action, care must be exercised because of possible prolonged exposure effects. The recommended dosage is from 1 to 3 pounds per 1000 cubic feet with an exposure of 12 to 24 hours.

Carbon Disulfide, CS_2, is a pale yellowish liquid, highly flammable, considerably heavier than water, and easily recognized by its distinctive unpleasant color. At room temperatures it rapidly changes to a gas which is slightly more than 2.5 times as heavy as air. When mixed with air over a wide range of proportions it is extremely explosive, so that care must be exercised that no spark or open flame is in the vicinity. Since it is considered to be more dangerous than gasoline, insurance companies may not cover losses from fires caused by its use. Although it can be applied alone at the rate of 1 pound per 100 bushels of grain, it is often mixed 1 part with 4 parts carbon tetrachloride to reduce the fire hazard. About 5 gallons of this combination is recommended for each 1000 bushels of grain. The quantity required depends on the temperature, the nature of the material to be fumigated, and the tightness of the enclosure. Since the gas is heavier than air the liquid must be exposed high in the space to be treated and in shallow pans to allow for quick evaporation. For fumigating other materials, such as clothing, fabrics, seeds, or cereals, the recommended dosage is 1 pound per 100 cubic feet. Veterinarians use it to rid horses of bots and intestinal worms.

Carbon Tetrachloride, CCl_4, is a clear liquid in closed containers at room temperatures, but when exposed to air it rapidly changes to a heavy gas which diffuses downward. For this reason, when employed as a fumigant, it must be released at the top of the fumigating chamber. Although not highly toxic to insects, it is commonly combined in mixtures with carbon disulfide or ethylene dichloride to reduce the fire hazard, since it is noncombustible. Not ordinarily recommended for large-scale fumigation operations, it is very convenient and practical for small spaces where expense is not a factor.

Carbon Dioxide, CO_2, is commonly employed with other fumigants to render them noncombustible and to aid in their effectiveness by causing the insects' spiracles to remain open, since it acts as a stimulant at concentrations of 3% or less. This gas in concentrations of 5% or more is an anesthetic for insects in laboratory experiments.

Ethylene Oxide, $(CH_2)_2O$, is a highly flammable liquid which becomes a gas at temperatures above 50° F. It is rendered safe by mixing with carbon dioxide. This mixture is marketed for commercial purposes under the name Carboxide. Although more effective at lower temperatures than some other fumigants, it should not be used on seeds because it reduces their germination.

Ethylene Dichloride, $C_2H_4Cl_2$, is another flammable liquid employed for grain fumigation, in the proportions of 1 part with 3 parts carbon tetrachloride at the rate of 5 to 6 gallons per 1000 bushels. It is less toxic than carbon disulfide to insects, and when mixed with carbon tetrachloride is considered to be a safe fumigant, even in the hands of inexperienced persons. In emulsifiable form, it is applied for the control of borers in peach trees.

Propylene Dichloride, $C_3H_6Cl_2$, has about the same toxicity and other characteristics as ethylene dichloride, but it is less volatile. It serves as a grain and soil fumigant. As an emulsion it has been recommended for controlling peach tree borers.

Paradichlorobenzene, $C_6H_4Cl_2$ or PDB, is a white crystalline substance that vaporizes slowly, usually at temperatures of 65° F. or above, to a gas that is over five times as heavy as air. Common as a repellent for fabric pests, its vapors are toxic if concentrated and confined. Although for a time widely used for peach tree borer control, it is being replaced by DDT. Dissolved in miscible oil it is still recommended for control of various borers in trees.

Orthodichlorobenzene, $C_6H_4Cl_2$, is a liquid isomer of the material just mentioned. It has been applied chiefly as a soil treatment for termites, either alone or in combination with other materials such as PDB or naphthalene. The liquid may burn the skin and the vapors are nauseating.

Naphthalene, $C_{10}H_8$, is a flaky, white crystalline material which readily passes into a vapor state at room temperatures or above, and serves primarily as a repellent for fabric pests, and occasionally as a fumigant to control thrips and spider mites in greenhouses. Although less toxic, it may substitute for PDB in households, but the objection to it is the persistent "moth-ball" odor.

Ethylene Dibromide, $C_2H_4Br_2$, is a colorless liquid with a relatively low volatility, rather recently developed as a soil fumigant for such pests as nematodes, wireworms, and Japanese beetle grubs. A waiting period of ten to fifteen days is required after soil treatment before it is safe to plant. When 5 to 10% of ethylene dibromide is added to a standard liquid grain fumigant the efficiency of the latter is improved in the surface layers of the grain.

Nicotine, $C_{10}H_{14}N_2$, has been employed as a fumigant primarily to con-

trol some insects in greenhouses. However, it is applied to perches in poultry houses to control chicken lice, and for aphids in the field on canning and truck crops with a special piece of equipment for producing the vapors. For greenhouses, commercial free nicotine is vaporized by applications to the heating pipes or other heating devices, but the common method is by Nicofume pressure fumigators. The nicotine is absorbed on a combustible material and, upon burning, releases the vapors. Because of many more effective insecticides, nicotine as a fumigant is less popular than in the past.

Chloropicrin, CCl_3NO_2, or tear gas, is an extremely irritating compound with high toxicity and good penetrating properties; it is heavier than air. It serves chiefly to fumigate flour mills, granaries, grain elevators, and as a soil fumigant. The main disadvantage is its persistent odor in the areas fumigated. For grain fumigation it is recommended at 2 pounds per 1000 cubic feet.

DD Mixture is a combination of 1,2-dichloropropane and 1,3-dichloropropene, which is used in soil fumigation to control rootknot nematodes, wireworms, grubs, and other pests. It must be handled with care because if spilled on the skin serious burns may result. Prolonged exposure to the vapors should also be avoided.

Azobenzene, $C_{12}H_{10}N_2$, a deep orange, crystalline solid melting at 68° C. has served as a miticide in greenhouses when vaporized by burning or applied as a paste to the heating pipes.

Miscellaneous Fumigants. This category includes those fumigants that have been developed but are now little used, or others still in the developmental stage. They are: dichloroethyl ether, sulfur dioxide, acrylonitrile, trichloroacetonitrile, hexachloroethane, tetrachloroethane, methyl formate, ethyl formate, methallyl chloride, trichloroethylene, cyanogen chloride, ethylene chlorobromide, sodium methyldithiocarbamate, and propylene oxide.

Repellents

Materials that prevent migration, oviposition, or feeding of insects are described as being repellent or having repellent properties. This effect is made manifest by the negative response of insects to the physical and chemical properties of these various substances when applied to plants, animals, buildings, soils, or anything to be protected from insect attack. Many of the better repellents are chemicals producing lethal effects, if the concentration is high enough and if the insects are unable to move away rapidly. Repellency to insects must be determined by experimentation since many substances obnoxious to man are not necessarily disagreeable to insects.

Bordeaux mixture is very repellent to potato flea beetles, leafhoppers and psyllids; *sulfur* applied to the body is a chigger repellent; *cattle fly sprays* prevent livestock from annoyance and loss of blood; *coal tar creosote* repels chinch bugs, termites, powder post beetles, and wood borers; *paradichlorobenzene, oil of cedar,* and *moth balls* are repellent to carpet beetles, clothes moths, and other fabric pests; *pine tar oil* prevents screw-worm flies from ovipositing in or near wounds of animals; *hydrated lime* and *aluminum sulfate,* applied to foliage, act as repellents for adult Japanese beetles; *oil of citronella, indalone, dimethyl carbate, diethyltoluamide, 2-ethyl-1,3-hexanediol, 2-phenylcyclohexanol, 2-cyclohexylcyclohexanol, dibutyl phthalate, dimethyl phthalate, benzyl benzoate,* and *Tabutrex* are repellents for mosquitoes, flies, ticks, and chiggers. During World War II, army uniforms were impregnated with dibutyl phthalate, benzyl benzoate, or dimethyl phthalate for protection against chiggers and related mites. Many of the aforementioned stomach, contact, or fumigant materials also possess some repellent properties.

Attractants

An agent or substance that has the power of eliciting a positive response by insects is called an attractant. Most of the better-known stimuli in this category are olfactory, and therefore chemical, but some insects are also attracted by certain wavelengths of sound and light. Male mosquitoes are attracted to sound waves in the range 430–540 vibrations per second. The adult Japanese beetles are collected in greater numbers from yellow traps.

The major types of chemical attraction are sex, oviposition, and food. Sex attractant secretions in insects are called *ectohormones* or *pheromones.* It is well-known that odors from unfertilized female cecropia moths, pink bollworm moths, gypsy moths, American cockroaches, pine sawflies, tobacco hornworm moths, and queen honey bees will attract the males. For some species this attraction is from great distances. These odors, infinitesimal in amount, bring immediate reaction from males of a particular species. A concentration of less than 10^{-14} micrograms of female sex pheromone wafted into a cage of American cockroaches will start them running around madly, vibrating their wings and trying to mate with each other. Similar behavior has been observed in other species studied.

Some of the better known male sex attractants are *anisyl acetone* and *cue-lure* for melon fly, *cue-lure* for Queensland fruit fly, *gyplure* for gypsy moth, *siglure, medlure,* and *trimedlure* for Mediterranean fruit fly, and *methyl eugenol* for oriental fruit fly. Because the flies devour methyl eugenol when lured to it, some believe it to be a food lure too.

Food attraction odors and oviposition stimuli also have been clearly demonstrated. Protein hydrolysates are attractants to fruit flies and have

been widely used in poisoned bait sprays. Other specific examples are *anethol, geraniol,* and *eugenol* in Japanese beetle traps; fermenting sugars and syrups attract many moths and butterflies; *metaldehyde* lures slugs and snails to calcium arsenate baits; *formalin* in low concentrations is both attractive and toxic to house flies; sheep blow flies are attracted to *keratin;* codling moth to *anethol;* oriental fruit moth to *terpinyl acetate;* fruit flies to *ammonium carbonate;* tobacco hornworm moths to *isoamyl salicylate;* and European chafer to *butyl sorbate.* There are many substances possessing attractant properties to insects. This is an area where further research should contribute much valuable information on new approaches to insect control. At present, attractants play a part in control primarily by luring the insects into traps or to poisoned food. The male annihilation technique of insect control depends on luring all males of a species to a sex attractant and poisoning them, leaving the females to die unfertilized. Attractants are also useful tools for insect survey work.

CHEMOSTERILANTS OR GROWTH REGULATORS

Chemicals capable of causing sterility in insects or other organisms are called chemosterilants or growth regulators. They may act in one of three ways: (1) inhibit the production of egg or sperm, (2) cause the death of the egg or sperm after having been produced, (3) bring about multiple dominant lethal mutations or severely damage the chromatin or genetic material in the egg or sperm. In the third type of action the egg and sperm remain alive and motile but the zygotes, if formed, do not develop into normal offspring. This is a desirable type of action in insect population control because the affected males compete with normal males for the available females; thus the mating requirements of the females are met as if mating with normal males.

Some of the more widely tested chemosterilants are aphamide, apholate, metepa, methiotepa, morzid, tepa, thiotepa, tretamine, and methotrexate. The insects and mites most often employed in tests with these compounds have been house fly, stable fly, screw-worm fly, Mexican fruit fly, citrus red mite, Mexican bean beetle, German cockroach, and mosquitoes.

Activity of chemosterilants is not restricted to insects; for instance, some of them have been used in cancer therapy. These chemicals must, however, be carefully evaluated as to their effects on other organisms.

At present no chemosterilants are recommended for insect or mite control. If any effective compounds are found safe for control purposes they will probably be used in combination with various attractants and poisoned baits. Potentially there should be greater population reduction with chemosterilants than with insecticides having similar intensity of action.

RESISTANCE TO INSECTICIDES

Continuous use of the same insecticide on a given population of insects or mites often results in the development of a tolerance or resistance to that chemical. This is not a new discovery because it was known that San Jose scale had developed resistance to lime-sulfur sprays in the state of Washington by 1908. From 1908 to 1945 only thirteen species of insects and ticks were recorded as being resistant to insecticides. Since 1945, with the increased use of the new synthetic organic insecticides, the number of resistant species has risen to over 200 in 1965, and it is still rising.

Resistance develops from chemical selection of the weak or susceptible individuals out of a population, leaving the tolerant individuals to reproduce. In general, pests with short life cycles develop resistance faster because the selection process proceeds more rapidly. Detoxication mechanisms within their bodies enable the animals to survive, and these survival factors can be passed on to future generations through genetic material. There is also evidence that a relationship exists between the diet of the animal and the degree of resistance. This phenomenon is not clearly understood.

Even though recommended dosages of insecticides are used, uneven distribution and dissipation of the toxicant between successive applications occur, enabling some of the tolerant individuals to survive. To cope with the resistance problem it is suggested that insecticide applications be as thorough as possible. When evidence of resistance is indicated a change should be made to another insecticide in a group entirely different from the one being applied. This alternation of different insecticides in a spray program has been termed "rotational spraying." It is not the solution to the resistance problem but is of some help while further studies are being made.

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6

Applied Insect Control: Mechanical, Cultural, Biological, Legislative

MECHANICAL CONTROL

The second important category for applied control is that of mechanical devices. Mechanical control usually involves the employment of special equipment or operations for the specific purpose of reducing insect populations or preventing attacks by them. To be effective these control measures must be initiated promptly, and the results are therefore immediate.

Barriers are devices to keep insects away from plants or animals. Some are still in use today in one form or another. Window screens, screen doors, and mosquito netting are barriers to all kinds of insects; metal shields on building foundations prevent subterranean termites from entering; in the field, dusty furrows check the advance of chinch bugs, armyworms, and similar migratory pests; sticky bands on trees and other objects trap and prevent migration of insects; shrouding young trees with cheesecloth prevents cicada injury; paper collars around single plants are barriers to cutworms; wrapping trunks of transplanted trees with paper prevents infestation of flatheaded borers; tree paints on pruning wounds are barriers to wood borers and carpenter ants; low metal, wood, or paper fences prevent migration of Mormon crickets and chinch bugs. Often chemicals are used in combination with many types of barriers.

Collection of insects by mechanical means may sometimes be the most practical method of control. Hand-picking egg masses, larval nests, or large insects often is the cheapest method of destroying them. Other devices for collecting or trapping insects are the following: hopperdozers for catching grasshoppers; inverting umbrellas for collecting curculios jarred

from trees; corrugated paper bands to trap codling moth larvae; house fly traps; Japanese beetle traps and other types utilizing the positive response of insects to sound, light, or odor, luring them into an inescapable chamber or electocuting device. Male mosquitoes are attracted by sound waves, and a great number of Japanese beetles are caught in yellow traps baited with geraniol, anethol, and eugenol (see attractants). Trap crops have been utilized in the control of insects. Attracting insects to plantings of their favorite food and then destroying them may result in the main crop remaining relatively free of injury.

Direct mechanical destruction may be accomplished by ensilage cutters, husker-shredders, heavy rollers, plows, and soil pulverizers. In areas where irrigation is possible, flooding reduces insect populations. Drainage ditches in marshes and swamps aid greatly in controlling such insects as mosquitoes and horse flies.

Artificially raising or lowering of the temperature may be employed as a means of control. Many insects are killed at temperatures of 110° to 115° F., and all are killed at exposures to 140° F. or higher. For example, some mills and grain elevators are equipped with heating systems enabling the temperatures inside to be raised to approximately 140° to 150° F. for several hours during periods of hot summer weather. This method is effective and often less costly than the application of fumigants. Infested clothing, baled cotton, cereals, and other foods may be effectively treated in this way if facilities are available for either large- or small-scale operations. It is well to keep in mind that tightly piled or compact products require longer exposure to allow for effective heat penetration. There is also shrinkage because of moisture loss, and the germination of seeds will be impaired by prolonged exposure at high temperatures. Sterilizing of soils with steam, dipping insect- and mite-infested bulbs in water at temperatures of 110° to 112° F., sponging the legs of horses with water at 115° F. to cause hatching of common bot fly eggs and resultant death of the larvae, or rotating infested logs toward the direct rays of the sun for killing bark beetles are other examples of control by heat.

Most insects become inactive at temperatures below 55° F. and may withstand hibernating temperatures of —25° F. or lower, but practically all activity ceases at 40° F. or lower. The knowledge of this fact has resulted in the construction of cold-storage vaults for protecting woolen clothing and furs during the summer. Usually low temperatures are not as effective as high temperatures for insect control, but, since there is no activity at near-freezing, no damage results. Sudden changes in temperature usually give higher mortality.

Exposing puparia of the screw-worm fly to the proper amount of gamma radiation results in sterile adults with normal mating behavior. Adult

screw-worm females mate only once and when sterile individuals are released in quantity over an infested area they react normally with the natural population, resulting in the production of many sterile eggs. Almost complete eradication of the screw-worm in the United States has been achieved by this control method which may prove applicable for controlling other insect species.

CULTURAL CONTROL

Cultural control measures are another means by which insect populations are reduced. These involve the best cropping practices known for a given crop that may incidentally check possible insect populations from developing. Many cultural operations destroy insects by mechanical means even though they may not be performed specifically for that purpose.

Fall plowing has long been considered beneficial in insect control and, where it fits in with the farm operations, is still to be commended. In this operation the control results partly from mechanical injury to the insects and partly from their exposure to unsuitable environmental conditions.

Deep and thorough plowing is a sanitation measure which often results in burial of insects, making it impossible for them to escape; this has been done to control such insects as corn borer, chinch bug, hessian fly, and other pests of field and garden crops. Another sanitation measure is burning weeds and crop remnants which harbor insects. However, this practice is generally condemned because the value of the crop remnants in soil conservation greatly offsets the possible gain in reducing an insect population. Burning destroys both beneficial and destructive insect species, as well as the nesting sites and hibernating quarters of birds and other vertebrate predators.

Frequent cultivation may kill insect life stages such as pupae of wireworms, and prevent others such as the corn root aphids and attendant ants from becoming established. Proper timing of cultivation may also be important in the destruction of less resistant life stages. Allowing land to remain idle or fallow is another means of control; specific examples are cutworms in Canada and sand wireworms in the southeastern states.

Insect damage may frequently be lessened by adjusting the dates of planting and harvesting. By delaying the planting of corn it is possible to avoid heavy infestations of corn earworm and corn borer. Sowing wheat on the "fly-free" dates to avoid hessian fly infestation is another example. Harvesting crops, threatened with injury, at a date somewhat earlier than usual may reduce insect damage, an example being pests of legume crops grown for hay. Leafhopper damage to alfalfa is often reduced by proper adjustment of the dates of cutting.

Crop rotation is the most widely employed farm-management practice

for the control of pests. For those pests that do not readily move from place to place it may be the only control measure needed. The concentration of one crop tends to permit a build-up of the pest population peculiar to that crop. This is due to the favorable food supply for the pest and often the lack of a constant food supply for the predators and parasites that keep it checked. Those natural enemies generally require alternate hosts to increase in numbers. Diversification in farming may be justified merely because it brings about conditions unfavorable to the development of destructive insect populations. The program is more effective if practiced throughout a given area.

Other cultural practices that may be unfavorable to the development of insect pests are the choice of good seed, proved varieties, proper seed-bed preparation, proper fertilizing and soil-conservation practices.

Reference: *U.S.D.A. Yearbook of Agriculture,* pp. 437–440, 1952.

BIOLOGICAL CONTROL

Biological control is considered by many to be the most important phase of applied control. Although it does not effect immediate reduction in insect populations as do some of our latest insecticides, over a longer period of time it may be more effective and more economical than chemical control. Biological control may be defined as the artificial manipulation of natural biological phenomena for the purpose of reducing or checking destructive populations of insects other animals or plants. It includes the use of resistant strains or varieties of plants or animals that have been developed through extensive research programs taking advantage of our knowledge of genetics. It also implies the introduction, mass rearing, and liberation of large numbers of predaceous or parasitic animals or disease-producing organisms. In other words it might be termed "biological warfare" against the enemies of man.

Frequently resistant varieties of plants have proved to be the best and most economical way of reducing or avoiding insect damage. Although not too well understood, our present knowledge indicates that resistance is due to either chemical, physical, or physiological factors, or combinations of these. By selection and hybridization experiments a number of good quality hybrid varieties of field corn resistant to European corn borer have been developed, as well as sweet corn hybrids showing a high degree of resistance to the attack of corn earworm. Resistance of Dual, Pawnee, and Ponca wheat to hessian fly attack has been demonstrated. Other examples of insect control by employment of resistant varieties of plants are given in the references at the end of this chapter.

Successful control of destructive insect populations by the liberation of large numbers of their natural enemies has been demonstrated. This type

of control consists of the distribution of many of the predators or parasites discussed under natural control from areas where they are abundant to areas where they are scarce. This is normally done by rearing them artificially under laboratory or insectary conditions, or collecting them in natural habitats where they are abundant. For example, hibernating lady beetles are collected in great numbers from the foothills of the Rocky Mountains, held in storage during the winter months, and then liberated in the spring and summer in regions where destructive populations of aphids and scales exist. Likewise, both native and introduced species of parasites of such insects as the gypsy and brown-tail moths, Japanese beetle, European corn borer, codling moth, and oriental fruit moth have been reared artificially by governmental or private agencies and distributed free or sometimes sold.

The introduction of the Australian or vedalia lady beetle, *Rodolia cardinalis* (Muls.), into California and Florida for controlling cottony-cushion scale in citrus groves is an outstanding example of biological control by a predator (Fig. 76). Establishment of the woolly apple aphid parasite, *Aphelinus mali* (Haldeman), in a number of other countries is an excellent example of biological control by a parasite. Other examples of biological control by parasitic insects are the establishment of the fly, *Lydella thompsoni* Herting, and the wasp, *Macrocentrus gifuensis* Ashm., for controlling the European corn borer; *Macrocentrus ancylivorus* Roh. and *M. delicatus* Cress. in peach orchards for controlling oriental fruit moth;

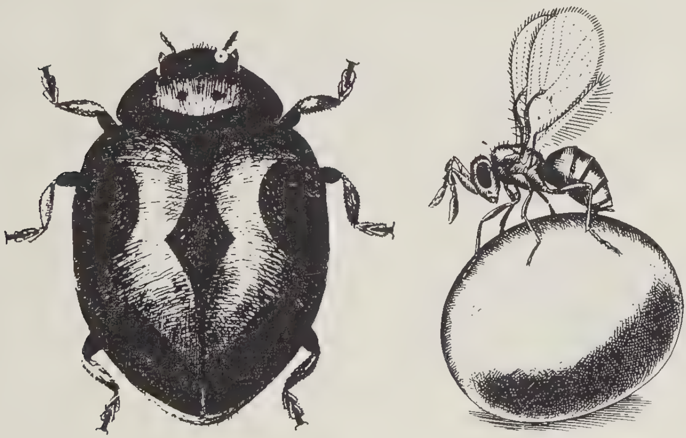

Fig. 76. The most famous of the predatory insects, the Australian or vedalia lady beetle, *Rodolia cardinalis* (Muls.), and possibly the most valuable egg parasite, *Trichogramma minutum* Riley. (U.S.D.A.)

black scale control on citrus in California by means of *Metaphycus helvolus* (Comp.); and citrophilus mealybug control by means of *Coccophagus gurneyi* Comp. and *Tetracnemus pretiosus* Timb. The introduction of a number of insects, especially the boring caterpillar, *Cactoblastis cactorum* (Berg.), into Australia to feed on and destroy the prickly pear is an example of successful biological control of a weed.

Many of our most serious pests are foreign invaders which were introduced without the parasites and predators that normally held them in check. Their change in habitat has resulted in a disturbance of the long-established balance of nature that had been reached in their original homes. To restore this balance, we import many promising natural enemies, after carefully investigating the possibility that they may become a plant pest or may be predaceous or parasitic on beneficial insects already present. Sometimes the introduced parasites or predators have survived and become as effective in checking insect populations as in their former habitats; at other times the insects fail to become established or do not increase in numbers to the point where any benefit results from their presence. Although there are good examples of plant-feeding insects being held in check by only one parasitic or predatory species it is usually a large and varied aggregation of such enemies, each operating when conditions chance to favor it, which reduces the population most effectively.

A little-considered phase of parasite establishment is the deliberate cultivation of plants which may harbor insects serving as alternate hosts. Studies along this line are few but they may result in ways of increasing beneficial parasite populations. For a one-host parasite this method would be of no value.

A way of encouraging predators and parasites would be to refrain from practices that interfere with them. Many of our modern insecticides destroy great numbers of our beneficial insects. This has resulted in the increase of pests formerly held in check by their natural enemies. For

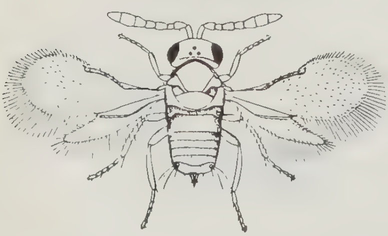

Fig. 77. *Prospaltella aurantii* (Howard), a minute parasite of scale insects.

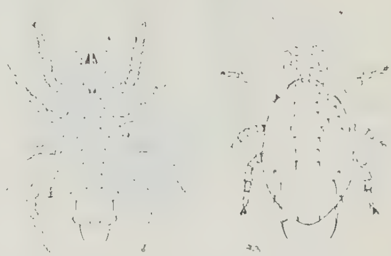

Fig. 78. Mite predators in the genus *Typhlodromus*. (U.S.D.A.)

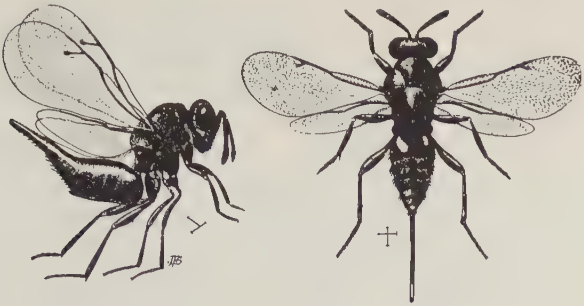

Fig. 79. *Eurytoma tylodermatis* Ashmead: (left) male, (right) female. Parasitic on the boll weevil. (U.S.D.A.)

example, European red mite, two-spotted spider mite, and red-banded leaf roller have increased in numbers since the introduction of DDT. This increase in population of mites is due, at least partly, to the fact that DDT kills predaceous mites in the genus *Typhlodromus* (Fig. 78), without affecting the plant-feeding mites. Examples of this selective action by insecticides show that at times spray applications may do more harm than good. More studies are needed concerning the habits and life histories of parasites and predators in order to integrate more effectively the joint action of both biological and chemical control measures.

Many disease-producing organisms discussed under natural control (pp. 68–70) are used in biological control. The estimated number of micro-organisms known to be pathogenic to insects is 250 viruses, 80 bacteria, 460 fungi, 250 protozoa, and 20 rickettsia. Mostly Lepidoptera are affected by them. Some have not proved to be practical, but this is probably due to lack of knowledge of the exact conditions required for their effective utilization. These organisms are restricted by environmental conditions in the same way as plants or animals. For example, chinch bug fungus,

Fig. 80. *Aphidius testaceipes* (Cress.), a braconid, the most useful parasite of aphids; (top left) antenna. (U.S.D.A.)

Fig. 81. *Carcelia laxifrons* Villeneuve, a tachinid parasite of the brown-tail moth. (U.S.D.A.)

Fig. 82. Female adult and cocoon of *Meteorus hyphantriae* Riley, a braconid parasite of the fall webworm. (U.S.D.A.)

Beauveria globulifera (Speg.), is naturally well distributed, and, when the conditions are favorable for its development, effective control results. The same is true for bacteria, protozoa, and viruses causing disease in insects. Failure to control a pest where these organisms are disseminated during periods unfavorable for their development should not be a reason for condemning them. Examples of biological control with disease-producing organisms are the following: inoculating infested soil with spores of *Bacillus popilliae* Dutky and *B. lentimorbus* Dutky, the causal agents of milky disease of Japanese beetle and twelve other coleopterous grubs; spraying plants with water suspensions of the spores of the brown, red, and yellow fungi for whitefly and scale control on citrus in Florida; dissemination of the bacterium *Bacillus thuringiensis* Berliner, as control agent for 112 species of Lepidoptera, including the alfalfa caterpillar in California; successful control of the European pine sawfly in Canada and the United States by application of a virus either by hand equipment or by airplane.

Soil-conservation and farm-management practices that encourage the presence or increase the populations of insect-feeding birds and other predatory animals should be considered of value in biological control. Top feeding minnows have successfully controlled mosquito larvae when introduced into certain swampy areas, and the giant toad of Central America has controlled white grubs attacking sugarcane since it was introduced into the West Indies, the Philippines, and the Hawaiian Islands.

References: C. P. Clausen, *Entomophagous Insects*, McGraw-Hill Book Co., New York, 1940; Paul De Bach and E. I. Schlinger, *Biological Control of Insects and Weeds*, Chapman

& Hall, London, 1964; R. H. Painter, *Insect Resistance in Crop Plants*, Macmillan Co., New York, 1951; E. A. Steinhaus, *Insect Microbiology*, Comstock Pub. Assoc., Ithaca, New York, 1946; E. A. Steinhaus, *Insect Pathology*, Vols. I and II, Academic Press, New York, 1963; H. L. Sweetman, *The Principles of Biological Control*, W. C. Brown, Dubuque, Iowa, 1958.

LEGISLATIVE CONTROL

Legislation in connection with insect control operates to authorize quarantines and provide funds for their support; to establish tolerances for poisonous residues on foods; to regulate the sale of insecticides in such manner as to protect the purchaser against fraud; to authorize and support extermination campaigns, and to provide facilities for investigational work needed to establish control practices.

Quarantines are designed to restrict the spread or introduction of insects, from an infested region to one not yet infested, from a part of the world where a known pest exists to other parts of the world to which it is not native and where it has not become established. The efficacy of quarantines must vary with the circumstances. In the absence of natural barriers an insect capable of flight may spread a certain distance each year. Such spread can seldom be limited by quarantines. Any insect may be transported, willfully or accidentally, through the activities of man, much greater distances than it would naturally migrate. Quarantines can never entirely prevent such spread, but they can do much to delay the establishment of a new pest in territory not infested. The work of quarantine officers is partly a police function; often it is largely educational in character. Officials have found that, where people are fully informed as to the purpose and need of a quarantine, the police powers need seldom be invoked and that a large measure of cooperation may be secured.

Quarantines designed to keep out of this country insects from foreign countries, other than Canada and Mexico, have a much better chance of success than those which are intended to restrict the movement of insects within the nation. Even though they cannot always succeed in preventing accidental introduction, the chances are reduced to a minimum through the operation of the quarantines. Quarantines of this character forbid the importation of materials which may possibly carry insects, or they require that such shipments be inspected and effectively treated before being released. Much material of this type is subjected to vacuum fumigation, a most effective safeguard.

Interstate quarantines cannot operate as effectively as the international quarantines; when they are supplemented by natural barriers to the spread of insects the chances of success of interstate quarantines are greatly increased. Quarantines established by California and other far western states may, for this reason, be justified whereas similar quarantines between eastern regions would be useless impositions on commerce. Where the

probable value is less than the cost of maintenance, quarantines should be discontinued. Obsolete quarantines against San Jose scale still exist in some states where the scale is universally established, apparently merely for the trifling revenue derived from them. Interstate quarantines have been more effectively maintained against the spread of the gypsy and brown-tail moths than against any other insects. In remarkably few cases isolated infestations have been discovered. More recently the quarantines have been supplemented by a barrier zone, which would seem to reduce still further the chances of these insects spreading. Most of the pests of Canada are also present in the United States, so that the question of international quarantines has not been important there. Certain insects present in Mexico constitute a menace to our citrus industry, and quarantines against them will probably have to be continued indefinitely. These quarantines seem to be very effective, and the Mexican government has cooperated very unselfishly in the execution of the necessary measures to render them so.

Some of the insects against which domestic and foreign quarantines have been established are the gypsy, brown-tail, and satin moths; the melon fly from Hawaii; the navel orange worm and orange fruitworm; the khapra beetle; the pink bollworm; the European chafer; the alfalfa weevil; the cereal leaf beetle; the white-fringed beetle; the vetch bruchid; the Mexican fruit fly; the Japanese beetle, and the Mediterranean fruit fly. A more exhaustive discussion of quarantines may be found in publications on the subject.*

Tolerances allowed for pesticide residues on foods are regulated by legislation. Tolerances are simply a method of expressing the amount of poisonous residue permissible on all foods in interstate commerce. They are expressed as parts per million (p.p.m.) or the parts of pesticide per million parts of food product.

The accepted value for each pesticide has been determined by careful laboratory feeding tests over a two-year period, using laboratory animals. The final figure is calculated to give a hundredfold factor of safety over the dosage that showed evidence of animal tissue damage. Pesticides that give any indication of being carcinogenic always have a zero or negligible tolerance. Zero or negligible residue levels are also established for calcium cyanide, HCN, some dinitro compounds, HETP, TEPP, mercury or selenium compounds, and a number of other pesticides when applied to certain crops. Many pesticides, such as some copper compounds, petroleum oils, some fumigants, synergists, botanicals and derivatives, are exempt from tolerances. Since the tolerance figures are different for various crops and

* *Calif. Bul.* 553, 1933; *U.S.D.A. Bur. Ent. Cir.* E-455, 1936; *Misc. Pub.* 80, 1946; *Cir.* 172, 1949; *U.S.D.A. Yearbook of Agriculture*, 360–364, 1952; ARS 22–91, 1965.

sometimes are changed, they are not listed here. The current listing is given each year in the U.S.D.A. Agriculture Handbook No. 313.

These regulations have been formulated under the Miller amendment to the Federal, Food, Drug, and Cosmetic Act which makes the Secretary of Health, Education, and Welfare responsible for protecting the public from foods exposed to dangerous amounts of pesticide chemicals.

No health hazards should develop if growers remain informed on proper pesticide use and heed the instructions on the package label.

*Insecticide regulation** is provided for by the Federal Insecticide, Fungicide, and Rodenticide Act of 1947, which became fully effective June 25, 1948. It provides for registration of all economic poisons with the Secretary of Agriculture through the Agricultural Research Service, Plant Pest Control Division, Pesticide Regulations Branch of the United States Department of Agriculture. Labels must state the name and address of the manufacturer; the name, brand, or trademark; the net contents; the ingredients including the chemical name or a well-known common name, and the percentage of active and inert materials. Highly toxic materials must carry a poison label with the skull and crossbones, a warning statement, and the antidote. Claims for the product must conform to the registration, and proof of claims is needed before registration is possible. The manufacturer guarantees that the poison conforms to the provisions of the Act. False or misleading statements on the label may lead to court action and, if convicted, the manufacturer may be fined, not to exceed $1000, imprisoned for not more than one year, or both.

Extermination campaigns are initiated when a new pest becomes established or when a new method of eradication involving well established pests is likely to succeed. Perhaps the best example of a new method of eradicating an old pest was that of the screw-worm from Florida and all other areas of the United States, except the lower tip of Texas. This was accomplished by releasing laboratory reared gamma radiated adults over the infested areas and is known as the sterility approach to insect control.

The outstanding example of extermination of a dangerous pest has been that of the Mediterranean fruit fly in Florida in 1929 and again in 1956–57. Less spectacular but also noteworthy has been the practical extermination of the cattle tick. Once a great handicap to the cattle industry over a large area of southern United States, the tick now is no longer considered a major pest.

The date palm scale (*Parlatoria blanchardi* Targ.-Toz.) was introduced into Arizona and California from northern Africa. An attempt to exterminate it was carried to a successful conclusion and quarantines against the insect have now been removed. In the eradication work the plants were

* *U.S.D.A. Yearbook of Agriculture,* p. 311, 1952.

cut back until only the trunks remained. These were seared with gasoline torches to kill all the insects. Trees so treated usually required a period of two years to resume their productive condition again.

Eradication of the gypsy and brown-tail moths has succeeded in several isolated locations where these insects have, from time to time, become established. The pink bollworm is still a dangerous pest of cotton and okra, and an eradication program is being carried out.

Ox warbles have been largely reduced or exterminated in some of the British Dominions and in parts of Europe by community effort. There is no reason why these insects, and horse bots as well, may not be exterminated by similar efforts in the United States. With some of our more recent and effective insecticides, we now have the tools to exterminate many of our pests. Although the magnitude of the effort required may be beyond our present resources, it is at least plausible that insects which are pests of a single crop, the boll weevil, for instance, could be practically, if not absolutely, exterminated over large areas.

Research funds for insect control programs are also provided through legislation by the state and federal governments. Most of this work is done at the state agricultural experiment stations and the laboratory and field stations of the Entomology Research Branch, Agriculture Research Service, United States Department of Agriculture, and Departments of Agriculture in other countries.

7

Insecticide Formulations, Applicators, and Dilution Tables

INSECTICIDE FORMULATIONS

Chemicals for insect control have to be properly formulated and diluted before they can be employed efficiently and without injury to animals or plants. Pure or undiluted insecticide chemicals are usually highly toxic to both animals and plants, and often their physical properties are such that they cannot be diluted easily. Without proper dilution excessive quantities are generally used, resulting in higher insect control costs. In addition applications heavier than necessary leave longer-lasting residues which are hazardous in many situations, especially on edible crops.

The common types of insecticide formulations are: dusts, emulsions, solutions, wettable powders, aerosols, and baits.

Dusts are usually made by diluting the toxicant with finely divided, ground plant materials, such as wheat, soybean, and walnut shell flours, or with minerals, such as talc, clays, and sulfur. Coarse or *granular* formulations of dusts are made for broadcast treatments by aircraft and are also adaptable for ground applicators.

Emulsions are made by dissolving the toxicant and an emulsifying agent in an organic solvent thus making emulsifiable concentrates. These are diluted with water and applied as sprays. At recommended dosages they can be used with safety on most plants; however, higher dosages may result in phytotoxicity.

Solutions consist of molecular mixtures of the toxicant with a solvent such as water, or with petroleum distillates such as kerosene. They may be applied by spraying, by dipping or impregnating, or by brushing. Oil solutions are phytotoxic and often constitute a fire hazard.

Wettable powders are toxicants absorbed or adsorbed on powders that can be readily mixed with water because a wetting or conditioning agent has been added. These form suspension-type sprays and must be constantly

agitated to give uniform coverage. At recommended dosages they are quite safe on most plants and are generally less costly. Abrasive action occurs on spray equipment much more rapidly when wettable powders are employed. *Flowables* are simply finely ground thick suspensions of a toxicant in water ready for further dilution.

Aerosols are air suspensions of solid or liquid particles of ultramicroscopic size which remain suspended for long periods. They may be the liquefied gas type utilizing the propelling agents Freon-12 or methyl chloride, or smokes, or mechanically generated oil clouds or fogs. The liquefied gas type is especially adaptable for the household and greenhouse and has shown results in outdoor situations where there is very little air movement. Mechanical fogging of alleys, wooded areas, swamps, and other breeding areas with DDT for fly and mosquito control has been practiced with some degree of success.

Baits consist of some attractive substance in combination with a poisonous chemical. Both liquid and dry baits have been formulated; which are employed depends on the pest and the circumstances under which it is to be controlled.

Insecticide Mixtures. Often the spraying or dusting operation is designed to control, by one application, several insect pests and some plant diseases as well; thus a mixture of materials can be used advantageously. In making such mixtures some knowledge of the effect of the different materials on each other is essential. If no deleterious effects are produced when different insecticides and fungicides are combined and applied simultaneously, they are said to be compatible. If the combination causes any kind of injury to the host, or lowered effectiveness of the components, or if it results in any other adverse effects, it is said to be incompatible. Compatibility charts are obtainable from pesticide companies and from some agricultural magazines. The Meister Publishing Co., Willoughby, Ohio, prints a new chart in color each year.

INSECTICIDE APPLICATORS

Numerous types of equipment are available for the application of pesticides. They range from small, hand-operated outfits to the large-capacity power machines capable of treating great acreages in a short time. From the selection available a careful choice should be made either of equipment designed for a special area of use or of a versatile piece of equipment which may fill many needs. Multiplicity of function is an important factor to consider.

Many types of hand-operated equipment are illustrated (Figs. 83 and 84) for home and garden vegetation purposes. Small bellows-type dusters and hand atomizers may be useful for the application of insecticides to control household pests or insects on house plants. Simple plunger-type dusters

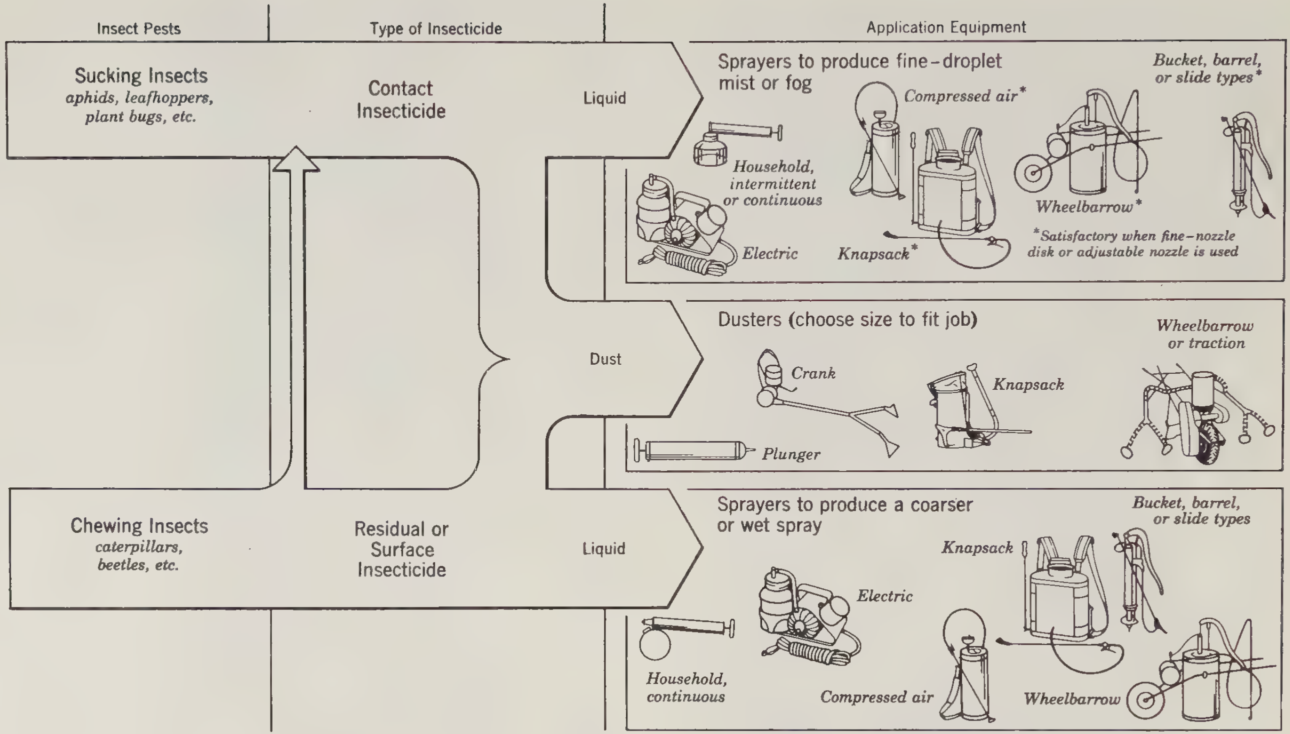

Fig. 83 Guide to selection of hand equipment for control of insects on vegetation. (U.S.D.A.)

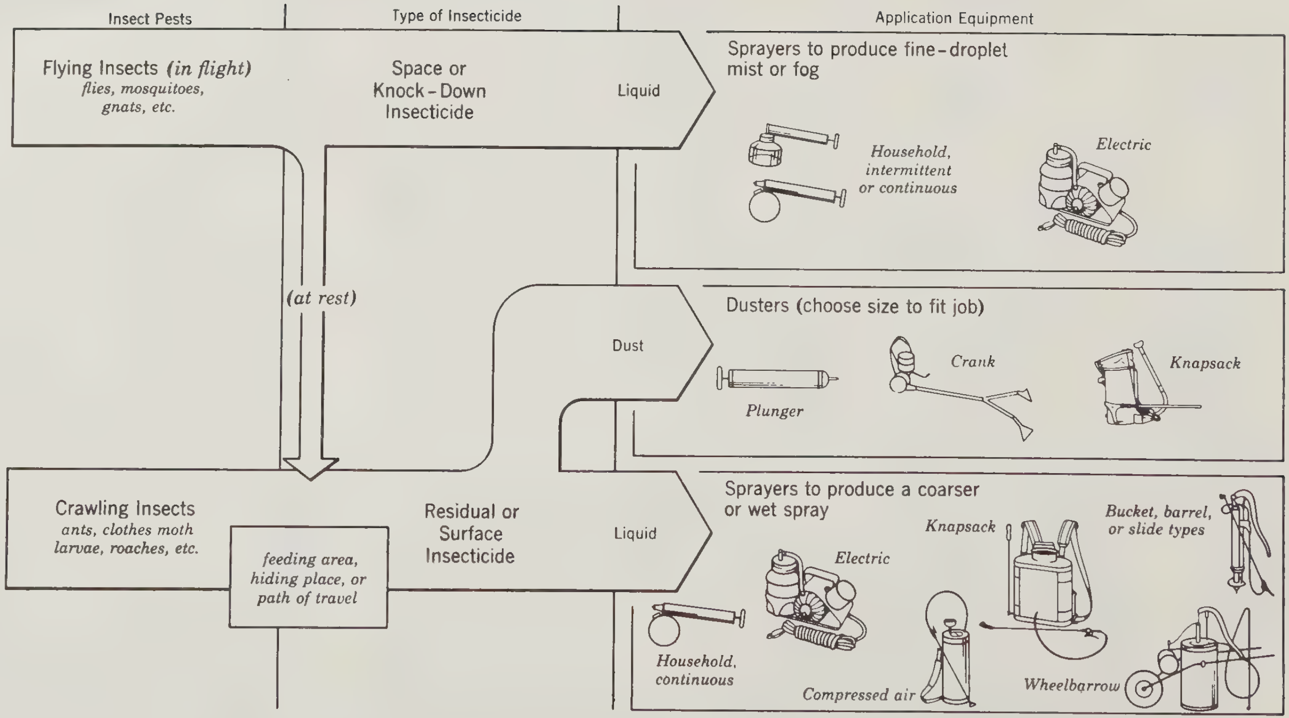

Fig. 84. Guide to selection of hand equipment for control of insects in and around buildings. (U.S.D.A.)

Fig. 85. A horse-drawn power duster in operation with outlets arranged for treatment of row crops. (U.S.D.A.)

Fig. 86. A tractor-mounted low-gallonage concentrate sprayer treating 8 rows of cotton simultaneously. (U.S.D.A.)

and sprayers of slightly greater capacity may suffice for small gardens. For the average small suburban garden, dusters of 1- or 2-quart capacity, or the compressed-air or knapsack-type sprayers, may fulfill the needs. The duster may be preferred because it is more quickly made ready for treat-

ments, and these are likely to be more frequent and timely, although dusts are generally more expensive. If more than one insecticide is applied, it is often advantageous to have two of these small dusters. Farm gardens of large size and small commercial truck gardeners need equipment with added capacity, such as crank or traction-type dusters, and gasoline engine-powered equipment. Regardless of the appliance selected, to be effective it must be adaptable for thorough coverage in order to give satisfactory control.

Larger farm operations require equipment of much greater size and power. Traction outfits may be used, but gasoline-powered equipment is more often employed with the mounting and nozzle arrangement varying according to the crop. Attachments for treating several rows at once are commonly provided. Low-pressure, low-volume, or concentrate sprayers are popular for field crops and are often tractor-mounted. High-pressure, high-volume sprayers are equally useful but necessitate the hauling of larger quantities of a diluted spray mixture. This is a disadvantage especially when applications are to be made after a rainy period.

Commercial orchardists must employ equipment of large size and capacity if the crop is to receive the maximum benefit. The optimum

Fig. 87. A tractor-mounted high-clearance sprayer applying DDT to corn. (U.S.D.A.)

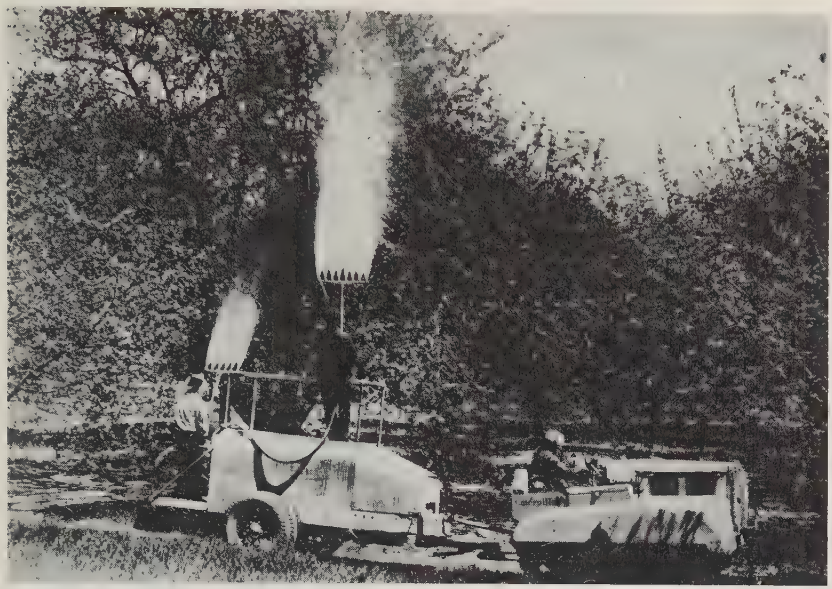

Fig. 88. Applying insecticides to orchard trees with an eight-nozzle spray broom. (Courtesy of the John Bean Manufacturing Co.)

period for the pesticide application may be less than a week, and part of the period may be unsuitable for treatment. Sprayers capable of covering the entire acreage within a period of two or three days are highly desirable. This means that the large grower must have several small outfits, requiring many operators, or a few high-capacity machines.

Modern hydraulic orchard sprayers have a tank capacity of 300 to 500 gallons or more and are capable of delivering 30 to 50 gallons of spray per minute at a pressure of 400 to 800 pounds per square inch. Multiple cluster nozzles, large-capacity, single-nozzle spray guns, or other nozzle groupings which permit the effective use of such quantities of sprays are available.

Fixed booms or spray masts are also made by some manufacturers. They are preferable where the trees are not large, as in peach and cherry orchards. This type of equipment is rapidly being replaced by the air blast- or mist blower-type machines, which require less manpower. One of these can replace up to three large-capacity hydraulic sprayers at a great saving in labor costs. The air blast sprayer consists of a powerful motor-driven fan which discharges a large volume of rapidly moving air behind a series of nozzles supplied by a low-pressure, low-volume pump. The air stream helps break up the liquid into small particles and carries them to the surface to be treated.

Fig. 89. A speed or air-blast sprayer in an orange grove. (U.S.D.A.)

Fig. 90. Eight-outlet power duster for orchard and other use. (Courtesy of Root Manufacturing Co.)

Truck- or trailer-mounted mist blowers are available for insecticide application to very tall trees or for treating a large number of row crops from the side of the field. Attachments are provided on some machines to apply both dusts and sprays simultaneously. These are called spray dusters or vapor dusters. They offer the added advantage of increased adherence of dust particles to foliage, and a reduction in the amount of inert carrier for insecticide applications.

Airplanes and helicopters have been effective in the application of sprays and dusts in many situations. Their great advantage is speed, and the fact that ground conditions do not hamper them. Cranberry bogs, rice fields, and forested areas, inaccessible to ground sprayers, can now be treated with ease from the air. Aircraft is widely employed for insecticide applications on cotton, corn, legumes, and some vegetable crops. Similar treatment of orchards generally has not given as good results as when ground equipment is used. This is often true of other crops as well, but, in spite of these limitations, aircraft has a definite place in agricultural pest control. The first aerial application of insecticides in this country was lead arsenate to control catalpa sphinx caterpillars (Fig. 91). Another illustration of insecticide application with aircraft is shown in Fig. 92.

Equipment Care. Application equipment needs to be cleaned and oiled systematically. The corrosive and abrasive properties of spray and dust materials make it essential for tanks and dust hoppers to be cleaned after each period of use. Pumps and accessories should be washed thoroughly with water to reduce corrosion and nozzle clogging troubles. Tanks, pumps, and engines must be drained during freezing weather. Lubrication of all wearing parts, according to the instructions provided by the manufacturer, will contribute to smooth operation and longer useful life. Replacement of worn parts as needed is good economy.

Fig. 91. The first application of insecticides from an airplane. (Courtesy of J. S. Houser, Ohio Agr. Exp. Sta.)

Fig. 92. Aerial spraying of forested areas by means of a helicopter. (U.S.D.A.)

Safety Precautions. Since insecticides vary greatly in their relative toxicities it is well to become acquainted with the product being applied. Read carefully all labels on the package before opening, and follow the directions explicitly. The following general precautions should be taken in handling and applying any insecticide. Avoid breathing dusts, spray mists, or vapors. For protection against the more toxic insecticides it is necessary to wear specially designed respirators or masks. Avoid skin contact with all insecticides, especially those formulated in oil. If this occurs, wash immediately and thoroughly with soap and water. Wear protective clothing

Dilution Tables for Insecticides

Insecticide Formulation	Formulation Needed per Acre to Obtain Following Amounts of Active Chemical per Acre				
	1/8 lb.	1/4 lb.	1/2 lb.	3/4 lb.	1 lb.
1% dust	12 1/2 lb.	25 lb.	50 lb.	75 lb.	100 lb.
5% dust	2 1/2 lb.	5 lb.	10 lb.	15 lb.	20 lb.
10% dust	1 1/4 lb.	2 1/2 lb.	5 lb.	7 1/2 lb.	10 lb.
25% wettable powder	1/2 lb.	1 lb.	2 lb.	3 lb.	4 lb.
40% wettable powder	1/3 lb.	2/3 lb.	1 1/4 lb.	1 7/8 lb.	2 1/2 lb.
50% wettable powder	1/4 lb.	1/2 lb.	1 lb.	1 1/2 lb.	2 lb.
75% wettable powder	1/6 lb.	1/3 lb.	2/3 lb.	1 lb.	1 1/3 lb.
10–12% emulsifiable concentrate					
1 lb. active ingredient/gal.	1 pt.	1 qt.	2 qt.	3 qt.	1 gal.
15–20% emulsifiable concentrate					
1 1/2 lb. active ingredient/gal.	1/3 qt.	2/3 qt.	1 1/3 qt.	2 qt.	2 2/3 qt.
25% emulsifiable concentrate					
2 lb. active ingredient/gal.	1/2 pt.	1 pt.	1 qt.	3 pt.	2 qt.
40–50% emulsifiable concentrate					
4 lb. active ingredient/gal.	1/4 pt.	1/2 pt.	1 pt.	1 1/2 pt.	1 qt.
60–65% emulsifiable concentrate					
6 lb. active ingredient/gal.	1/6 pt.	1/3 pt.	2/3 pt.	1 pt.	1 1/3 pt.
70–75% emulsifiable concentrate					
8 lb. active ingredient/gal.	1/8 pt.	1/4 pt.	1/2 pt.	3/4 pt.	1 pt.

Dilution Tables for Insecticides—*Continued*

Insecticide Formulation	Formulation Needed per 100 Gallons of Water to Obtain Following Percentages of Actual Chemical				
	0.25%	0.5%	1%	2%	5%
25% wettable powder	8 lb.	16 lb.	32 lb.	64 lb.	160 lb.
50% wettable powder	4 lb.	8 lb.	16 lb.	32 lb.	80 lb.
75% wettable powder	2 2/3 lb.	5 1/3 lb.	10 2/3 lb.	21 1/3 lb.	53 1/3 lb.
12% emulsifiable concentrate					
1 lb. active ingredient/gal.	2 1/12 gal.	4 1/6 gal.	8 1/3 gal.	16 2/3 gal.	41 2/3 gal.
20% emulsifiable concentrate					
1 1/2 lb. active ingredient/gal.	1 1/4 gal.	2 1/2 gal.	5 gal.	10 gal.	25 gal.
25% emulsifiable concentrate					
2 lb. active ingredient/gal.	1 gal.	2 gal.	4 gal.	8 gal.	20 gal.
45% emulsifiable concentrate					
4 lb. active ingredient/gal.	1/2 gal.	1 1/8 gal.	2 1/4 gal.	4 1/2 gal.	11 1/4 gal.
75% emulsifiable concentrate					
8 lb. active ingredient/gal.	1/3 gal.	2/3 gal.	1 1/3 gal.	2 2/3 gal.	6 2/3 gal.

during each application and wash thoroughly before wearing again. Do not smoke or eat until the face and hands have been washed thoroughly after the handling or applying of insecticides. Store all insecticides where they cannot be reached by children. Dispose of empty pesticide containers in the manner prescribed on the package. If all these precautions are followed there is no excuse for fatalities from the use of insecticides.

Dilution Table for Liquid Insecticides

Amount of Finished Spray	Amount of Spray Material for Dilutions			
	1–200	1–400	1–600	1–800
1 qt.	1 tsp.	½ tsp.	⅓ tsp.	¼ tsp.
1 gal.	4 tsp.	2 tsp.	1½ tsp.	1 tsp.
5 gal.	3½ oz.	1⅗ oz.	1 oz.	⅘ oz.
50 gal.	1 qt.	1 pt.	⅔ pt.	½ pt.

Proportionate Quantities of Liquid Insecticides for Various Quantities of Water

Quantities of Water	Quantities of Materials				
100 gal.	½ pt.	1 pt.	1 qt.	2 qt.	1 gal.
	8 fl. oz.	16 fl. oz.			
25 gal.	2 fl. oz.	4 fl. oz.	8 fl. oz.	1 pt.	1 qt.
	59.2 ml.			16 fl. oz.	
5 gal.	11.8 ml.	23.7 ml.	1.6 fl. oz.	3.2 fl. oz.	6.4 fl. oz.
			47.3 ml.	94.6 ml.	189.3 ml.
1 gal.	2.4 ml.	4.7 ml.	9.5 ml.	18.9 ml.	1.3 fl. oz.
					37.9 ml.
1 qt.	0.591 ml.	1.183 ml.	2.366 ml.	4.732 ml.	9.463 ml.
1 liter	0.625 ml.	1.250 ml.	2.500 ml.	5.000 ml.	10.000 ml.

Proportionate Quantities of Powdered Insecticides for Various Quantities of Water

Quantities of Water	Quantities of Materials				
100 gal.	1 lb.	2 lb.	3 lb.	5 lb.	6 lb.
25 gal.	4 oz.	8 oz.	12 oz.	1 lb. 4 oz.	1 lb. 8 oz.
5 gal.		1.6 oz.	2.4 oz.	4 oz.	4.8 oz.
	22.7 g.	45.4 g.	68.0 g.	113.4 g.	136.1 g.
1 gal.	4.5 g.	9.1 g.	13.6 g.	22.7 g.	27.2 g.
1 qt.	1.134 g.	2.268 g.	3.402 g.	5.670 g.	6.804 g.
1 liter	1.198 g.	2.397 g.	3.595 g.	5.991 g.	7.190 g.

CAPACITY OF SPRAYER TANKS

The capacity, in gallons, of the tanks on sprayers may be calculated as follows:

Cylindrical tanks: Multiply length by square of the diameter, in inches, by 0.0034.

Rectangular tank: Multiply length by width by depth, in inches, by 0.004329.

Tanks with elliptical cross section: Multiply length by short diameter by long diameter, in inches, by 0.0034.

Rates of Field Application

1 oz./sq. ft.	= about 2722.5 lb./acre.
1 oz./sq. yd.	= about 302.5 lb./acre.
1 lb./100 sq. ft.	= 435.6 lb./acre.
1 pt./sq. rod	= 20 gal./acre.
1 g./sq. ft.	= about 96 lb./acre.

Based on rows 3 ft. apart and 100 gal. of spray per acre, 1 gal. will cover 145 row ft. or about 1 qt. per 36 row ft. With rows 3 ft. apart and 25 lb. of dust per acre, 1 lb. of dust will treat 581 row ft. or 2.8 oz. per 100 row ft.

Dilution Method for Liquids

Liquids of known strength, as commercial 95% alcohol, may be easily diluted to any lower strength as follows: Into a 100-ml. graduate pour as many milliliters of the stronger solution as the percentage required in the weaker one. Then add water (or the diluent being used) until the mixture reaches the milliliter mark equivalent to the percentage of the stronger solution.

For example, to make 70% from 95% alcohol, pour into the graduate 70 ml. of the 95% alcohol and fill to the 95-ml. mark with water. The result is 95 ml. of a 70% strength of alcohol. The percentages obtained by this procedure must be expressed in terms of volume, not weight.

Spray Solution Required per Tree

	Average Amount per Application, gallons			
Age of Trees, Years	Apples	Peaches	Sour Cherries	Sweet Cherries
2–3	0.5	0.7	0.5	0.5
5	1.5	3.0	2.5	1.5
10	6.0	5.5	6.0	6.0
12	8.0	6.0	8.0	8.0
15–20	12–20	6.0	10.0	10.0
21–25	20–35		12.0	15–18

Quantity of Oil Emulsion Concentrates

If % Oil in Stock Is:		If Percentage Oil Desired in Spray Tank Is:				
	1.0	1.2	1.3	1.4	1.5	1.6
	Use Number of Gallons of Stock Shown Below for Each 100 Gallons of Water					
99–100	1.0	1.2	1.3	1.4	1.5	1.6
97–98	1.02	1.22	1.33	1.48	1.54	1.64
92	1.09	1.30	1.41	1.52	1.63	1.74
90	1.11	1.33	1.44	1.56	1.67	1.78
83–84	1.20	1.44	1.56	1.68	1.80	1.92
80	1.25	1.50	1.62	1.75	1.88	2.00
65	1.54	1.85	2.00	2.15	2.31	2.46

Conversion Tables and Equivalents

Linear Measure:

1 inch = 2.54 centimeters = 25.4 millimeters.
1 foot = 12 inches = 30.5 centimeters = 0.3048 meter.
1 yard = 3 feet = 0.9144 meter.
1 rod = 5.5 yards = 16.5 feet = 5.029 meters.
1 mile = 160 rods = 1760 yards = 5280 feet = 1.6094 kilometers.
1 micron = 0.001 millimeter.
1 millimeter = 0.0394 inch = about $\frac{1}{25}$ inch.
1 centimeter = 10 millimeters = 0.3937 inch = about $\frac{2}{5}$ inch.
1 decimeter = 10 centimeters = about 4 inches.
1 meter = 10 decimeters = 3.28 feet = 39.37 inches.
1 kilometer = 1000 meters = 0.6214 mile.

Square Measure:

1 square foot = 144 square inches = 0.0929 square meter.
1 square yard = 9 square feet = 0.8361 square meter.
1 square rod = 272.25 square feet = 30.25 square yards = 25.293 square meters.
1 acre = 43,560 square feet = 4840 square yards = 160 square rods = 0.4047 hectare.
1 square mile = 640 acres = 259.000 hectares.
An area 4 rods by 4 rods = 16 square rods = 0.1 acre.
1 square meter = 1550 square inches.
1 hectare = 2.471 acres = 10,000 square meters.

Capacity Measure (cubic):

1 cubic inch = 16.387 cubic centimeters.

1 cubic foot = 1728 cubic inches = 29.922 U.S. liquid quarts = 25.714 U.S. dry quarts = 0.80357 U.S. bushel = 28.316 liters.

1 cubic yard = 27 cubic feet.

Capacity Measure (liquid):

1 level tablespoonful = 3 level teaspoonfuls.

1 fluid ounce (U.S.) = 2 tablespoonfuls = 29.57 milliliters.

1 cupful = 8 fluid ounces.

1 pint = 2 cupfuls = 16 fluid ounces = 473.2 milliliters.

1 quart (U.S.) = 2 pints = 32 fluid ounces = 0.9463 liter = 0.8327 quart (Brit.).

1 gallon (U.S.) = 4 quarts = 128 fluid ounces = 0.8333 gallon (imperial or Brit.) = 231 cubic inches = 0.1337 cubic foot = 3.785 liters.

1 quart (Brit.) = 40 fluid ounces (Brit.) = 1.1365 liters.

1 gallon (Imperial or Brit.) = 4 quarts (Brit.) = 1.2009 gallons (U.S.) = 277.5 cubic inches = 4.546 liters.

1 milliliter = almost exactly 1 cubic centimeter.

1 liter = 1000 milliliters = 1.057 liquid quarts (U.S.).

Capacity Measure (dry):

1 quart (U.S.) = 2 pints = 67.20 cubic inches = 1.1012 liters = 0.9690 quart (Brit.).

1 bushel (U.S.) = 32 quarts = 4 pecks = 1.244 cubic feet = 35.238 liters.

1 quart (Brit.) = 1.0320 quarts (U.S.).

1 bushel (Brit.) = 8 gallons = 1.2843 cubic feet = 36.368 liters.

1 liter = 0.9081 dry quart (U.S.).

Weight:

1 grain = 64.7989 milligrams.

1 ounce (avoirdupois) = 437.5 grains = 28.3495 grams.

1 pound (avoirdupois) = 16 ounces = 7000 grains = 453.59 grams.

1 ton (U.S. short) = 2000 pounds = 0.893 long ton = 907.185 kilograms.

1 ton (U.S. long; Brit.) = 2240 pounds = 1.120 short tons = 1016.047 kilograms.

1 microgram = 1 gamma = 0.001 milligram.

1 gram = 1000 milligrams = 15.432 grains = 0.0353 ounce.

1 kilogram = 1000 grams = 35.27 ounces = 2.205 pounds.

1 ton (metric) = 1000 kilograms = 2204 pounds = 0.984 long ton = 1.1023 short tons.

1 milligram per kilogram = 1 part per million = 0.007 grain per pound.

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8

Insects Injurious to Various Crops

Many of our major insect pests attack a variety of hosts. To avoid repetition this chapter discusses some of them in detail; the reader will be referred to this section in later chapters.

GRASSHOPPERS OR LOCUSTS

Order Orthoptera, Family Acrididae or Locustidae

Grasshoppers or locusts are one of the most serious insect pests of crops in many areas of the world. Although there are many species responsible for much local destruction, only five are important, causing about 90% of the grasshopper damage to cultivated crops in the United States. These are the differential grasshopper, *Melanoplus differentialis* (Thos.); the red-legged grasshopper, *M. femur-rubrum* (DeG.); the two-striped grasshopper, *M. bivittatus* (Say); the Rocky Mountain grasshopper, *M. spretus* (Walsh); the migratory grasshopper, *M. sanguinipes* (F.); the devastating grasshopper, *M. devastator* Scudder; and the clear-winged grasshopper, *Camnula pellucida* (Scudder) (see Figs. 93, 94, 95, and 96).

Other species of importance in some areas are the following: *Melanoplus dawsoni* (Scudder), *M. packardii* (Scudder), the Nevada sage grasshopper, *M. ruggelsi* Gurney; the High Plains grasshopper, *Dissosteira longipennis* (Thomas); the Carolina grasshopper, *D. carolina* (L.); the big-headed grasshopper, *Aulocara elliotti* (Thomas); the lubber grasshopper, *Brachystola magna* (Gir.); and the American grasshopper, *Schistocerca americana* (Drury).

The Rocky Mountain grasshopper is considered the important migratory species in the United States and Canada. Other species develop what appears to be at least a partial migratory habit in seasons of great abundance and short food supply. Not all the conditions responsible for grasshopper outbreaks are thoroughly understood. They are, however, known

Fig. 93. (Left) *Melanoplus sanguinipes* (F.) and (right) *M. differentialis* (Thos.). (Dean, Kansas Agr. Exp. Sta.)

Fig. 94. *Melanoplus femur-rubrum* (DeG.); (left) female; (right) male. (Walton, U.S.D.A.)

Fig. 95. *Camnula pellucida* (Scudder). (Walton, U.S.D.A.)

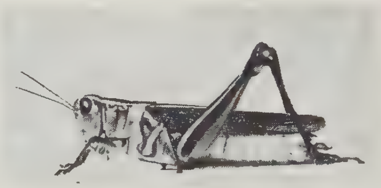


Fig. 96. *Melanoplus bivittatus* (Say). (Dean, Kansas Agr. Exp. Sta.)

to be climatic and biological in character. Prediction of probable infestations is done by making careful counts of eggs present in the areas concerned a few months in advance of hatching. This information helps in planning an effective control campaign.

The injurious species of grasshoppers agree in the main features of their cycle of development. Eggs of all are deposited in late summer in elongated masses or pods inserted in the soil (Figs. 97 and 98) of grain, grass, or other crops, but sod clumps receive the greater number of eggs of the differential, two-striped, and clear-winged species. These pass through the winter, and, on hatching in the spring, the young seek food in the immediate vicinity. As they increase in size and food becomes scarce, migration to other sources takes place. After molting 5 or 6 times,

Fig. 97. *Melanoplus bivittatus* (Say) depositing eggs in the soil. (Walton, U.S.D.A.)

Fig. 98. Grasshopper egg pods at the bases of grass roots. Insert, a partly opened pod showing individual eggs. (Severin and Gilbertson, S. D. Agr. Exp. Sta.)

during a period of 40 to 60 days, the adults appear and continue feeding until cold weather kills them. If their food supply becomes exhausted, adult migration takes place by flight. Great hordes of migrating grasshoppers have been observed in other countries, but this habit is infrequent in the United States. Oviposition begins shortly after the adults appear and, because of irregularities in hatching time and variation in rate of development, continues for nearly 3 months. The egg pods of the clear-

winged and migratory species usually contain 15 to 20 eggs, and those of the two-striped and differential species have 50 to 75. A single female lays 200 to 400 eggs over a period of several weeks. The number of pods laid by each female varies according to the species, the food supply, and weather conditions.

Grasses are said to be the normal food of grasshoppers, but they feed on nearly any kind of vegetation and when numerous may destroy every green plant within their line of march. After regular crops and all grasses are destroyed they frequently feed on the bark and leaves of deciduous trees.

Fluctuation in population of the hoppers indicates variation in the operation of the natural controlling influences. A succession of warm dry seasons is favorable for the development of serious grasshopper outbreaks. Cool wet weather with long periods of high humidity is unfavorable for grasshopper development. A season with the following characteristics would favor heavy mortality: weather warm enough in early spring to cause considerable premature hatching, followed by temperatures low enough to prevent normal growth; a short period of hot weather late in the spring to insure complete hatching of the remaining eggs, with long periods of cloudy, wet weather favorable to grasshopper diseases; a cool summer and early fall to delay maturity and to shorten the time for egg-laying.

Several important natural enemies reduce grasshopper populations. Blister beetles, ground beetles, anthomyiid flies (Fig. 99), and bee flies lay their eggs in the soil near or in the egg pods. Their larvae have been known to destroy from 40 to 60% of all grasshopper eggs laid over large

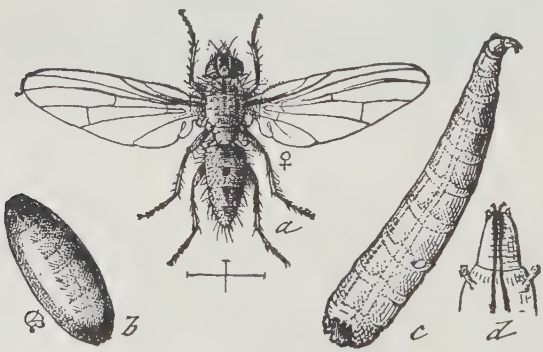


Fig. 99. *Anthomyiid* egg parasite of grasshoppers; *a*, fly; *b*, puparium; *c*, larva; *d*, enlarged head of larva. (Riley.)

areas. The flesh fly, *Blaesoxipha kellyi* (Aldrich), deposits active larvae upon grasshoppers, often while in flight, resulting in high mortality.

Threadworms are frequently important as internal parasites. Many birds and mammals, as well as predatory insects, feed on grasshoppers. When the climatic factors are favorable for the development of the common and widely distributed fungi, *Beauveria globulifera* (Speg.) and *Empusa grylli* Fresenius, grasshoppers become diseased and die.

Applied control is practiced in many ways. Collection of adults by hopperdozers, or plowing and disking, to destroy overwintering eggs are of some value in control but are not widely practiced at the present time. The more recently developed chemicals have revolutionized grasshopper control. Application to the hatching areas of any of the materials indicated in the following table gives effective kill.

Amount per Acre of Pure Chemical

	Sprays	Dusts
Carbaryl	$\frac{1}{2}$–1 lb.	1–$1\frac{1}{2}$ lb.
Chlordane	$\frac{1}{2}$–1 lb.	$\frac{3}{4}$–$1\frac{1}{2}$ lb.
Diazinon	8–12 oz.	12–16 oz.
Malathion	1–$1\frac{1}{2}$ lb.	$1\frac{1}{2}$–2 lb.
Naled	12–14 oz.	14–16 oz.
Toxaphene	1–$1\frac{1}{2}$ lb.	$1\frac{1}{2}$–$2\frac{1}{2}$ lb.

For young grasshoppers in short vegetation the lower dosages are recommended. The higher dosages are suggested later in the season for barrier strips around gardens or fields, when the vegetation is taller, the grasshoppers are larger, or when a longer-lasting residue is desired. Emulsifiable concentrates and wettable powders should be diluted with water to suit the available spraying equipment.

Poisoned baits are still a practical control in some areas. These vary in composition, but a common formula consists of 25 pounds of mill-run bran, 3.5 bushels of sawdust, a choice of 2 ounces of aldrin, dieldrin, or heptachlor, 8 ounces of chlordane, 1 pound of toxaphene, 6 pounds of sodium fluosilicate, or a half gallon of liquid sodium arsenite, with enough water added (usually 10 to 12 gallons) to make a moist crumbly mash. This bait may be spread by hand for small areas, but broadcasting machines have been adopted for larger acreages. Use 20 pounds of bait per acre and make the application early in the morning when grasshopper feeding is heaviest.

Dry baits are preferred to wet baits for application by airplane. Im-

pregnate 100 pounds of coarse bran with a half gallon of a purified grade kerosene or fuel oil containing either 2 ounces of aldrin, dieldrin, or heptachlor, 8 ounces of chlordane, or 1 pound of toxaphene. An effort should be made to obtain uniform distribution of the small quantity of solution throughout the dry bran. The recommended dosage is 5 to 10 pounds of dry bait per acre.

All the chemicals suggested for controlling grasshoppers are highly toxic to man and other animals; therefore care should be exercised when handling them. Selection of the proper chemical for use on a particular crop should be made with the help of your agricultural extension specialist.

References: *U.S.D.A. Tech. Bul.* 774, 1941; 1165, 1957; 1167, 1958; *Farmers' Bul.* 2193, 1964; *Agr. Inf. Bul.* 287, 1964; *Canada Dept. Agr. Pub.* 1036, 1958; *J. Econ. Ent.*, 45:684, 1952.

MORMON CRICKET

Anabrus simplex **Hald., Family Tettigoniidae**

The Mormon cricket is not a true cricket but is more closely related to katydids and meadow grasshoppers. Its common name comes from the fact that an outbreak of the insect did vast damage during the early days of the Mormon colony in Utah. According to legend this outbreak was suppressed by sea gulls, and a monument was erected in commemoration of this event. It is an insect of long standing as a pest, but one which has usually been of minor importance. Presumably the conditions that favor great grasshopper outbreaks also are responsible for a marked increase and abundance of this pest.

Mormon crickets are found in the intermountain states of Colorado, California, Kansas, Wyoming, Montana, Idaho, Utah, Nevada, Oregon, Washington, North Dakota, South Dakota, Minnesota, New Mexico, Nebraska, and bordering Canadian Provinces.

The flightless adults resemble crickets (Fig. 100). They deposit eggs singly or in small groups in the soil during late summer, and hatching

(*a*) Fig. 100. Mormon crickets; *a*, female; *b*, male. (U.S.D.A.) (*b*)

takes place the following spring. Feeding and seven successive molts follow, the adult stage appearing again in early summer sixty to ninety days after hatching. All plants in the infested area may be attacked, but grasses are preferred, and, as the food supply becomes exhausted, migration to other areas takes place. The injury to plants is due to removal of vegetative and reproductive parts, breaking of the stalks by the weight of the feeding insects, or girdling of twigs.

Natural control results from a variety of predators such as birds and small mammals. Applied control is accomplished by poisoned baits and by chemical treatment of infested areas, as described under grasshoppers (pp. 133–134).

References: *U.S.D.A. Tech. Bul.* 161, 1929; *Tech. Bul.* 1202, 1959; *Cir.* 575, 1940; *Tech. Bul.* 866, 1943; *Farmers' Bul.* 2081, 1962.

FIELD CRICKET

Acheta assimilis Fabr., Family Gryllidae

Although this cricket is often regarded as a household pest of minor importance, it can cause serious damage to garden and field crops. Widely distributed in both North and South America, it has been found damaging cotton seedlings, seeds of alfalfa and grain crops, strawberries and garden vegetables, especially tomatoes. In houses they may eat holes in clothing and furnishings, or feed on stored tubers or fruits.

In the latitude of South Dakota crickets produce one generation per year, overwintering as eggs in the soil. There may be as many as two or three generations per year in the Imperial Valley in California and in some of the Gulf states, where they are usually active year round. In

Fig. 101. The field cricket, *Acheta assimilis* Fabr., a general feeder. (Gilbertson, S. D. Agr. Exp. Sta.)

the northern states, egg-hatching begins in late May or during June, and after eight to twelve nymphal instars the dark brown-to-black adults (Fig. 101) appear by the latter part of July. Mating, feeding, and ovipositing occur thereafter and continue until cold seather kills the adults.

Control measures in the field are the same as those prescribed for grasshoppers (pp. 133–134). In houses, crickets can be effectively eliminated by applying a 2% chlordane solution or 5% chlordane dust to the shaded areas where they normally hide. Because of its toxicity to man, this chemical should not be applied to stored tubers, baskets of fruits, or to any other foods.

References: *U.S.D.A. Tech. Bul.* 642, 1939; *Agr. Inf. Bul.* 237, 1962; *S.D. Bul.* 295, 1935.

WHITE GRUBS OR MAY BEETLES

Phyllophaga spp., Family Scarabaeidae

White grubs or grubworms of which there are over 100 different species, are larvae of May and June beetles. These beetles are from a half inch to an inch in length, vary from light to dark brown in color, and

Fig. 102. A common May beetle, *Phyllophaga rugosa* (Melsheimer), and its larva, a white grub. (U.S.D.A.)

are robust in form (Fig. 102). They eat the leaves of both deciduous and coniferous trees. The larvae or grubs are white, curve-bodied, with brown heads and three pairs of legs. The hind part of the abdomen usually appears darker because the soil particles inside show through the body wall. The grubs feed on the roots of bluegrass (Fig. 103), timothy, corn, soybeans, and other crops, and on the tubers of potatoes. They often ruin bluegrass pastures in the north central states and may become serious as pests of lawns and nursery plantings. Most severe damage occurs on crops that follow grass sod.

The life cycle of the more abundant and injurious species extends over

three years. In late spring the pearly white eggs are deposited 1 to 8 inches deep in the soil. Since the beetles are attracted to trees, they tend to concentrate their egg-laying in the higher portions of timothy and bluegrass sod near wooded tracts. About three weeks later the eggs hatch

Fig. 103. White grubs underneath sod which has been loosened by their feeding. (Davis, U.S.D.A.)

into young larvae which feed on living roots and decaying vegetation throughout the summer. In the autumn they migrate downward and remain inactive until the following spring when they return to feed on the roots of plants near the soil surface. The greatest damage occurs during this period. The next autumn they again go deep into the soil, returning near the surface in the spring of the third year when they feed, as before, until about June. Then oval earthen cells are made and pupation follows. The adult beetles emerging from these pupae a few weeks later remain in the pupal cells through the winter and emerge from the soil the following year in May and June when feeding, mating, and egg-laying take place. The new adults are attracted in great numbers to lights at night. The usual life cycle of white grubs is shown in Fig. 104. In the northern range of these insects, four years are sometimes required for complete development, whereas in the latitude of Texas the period from egg to adult seems to be two years for most species. The annual white grub or northern masked chafer, *Cyclocephala borealis* Arrow, completes its life cycle in one year and is commonly a pest of lawns (see p. 324).

Since the common species have a three-year cycle it follows that there must be three broods if the adults are seen every year. The broods are not equally extensive; the heaviest infestation is from brood *A*, adults

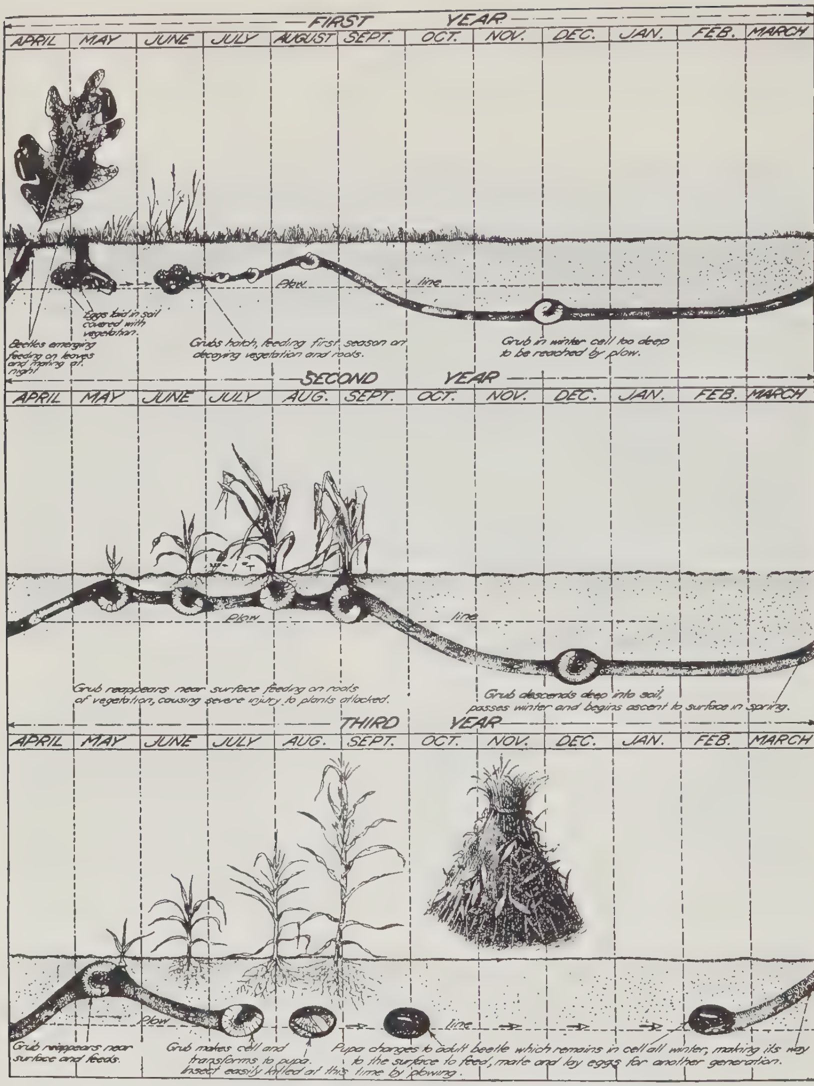


Fig. 104. Life history of white grubs. (Davis, U.S.D.A.)

of which will appear in 1968, 1971, 1974, and every three years thereafter; next in abundance is brood *C*, adults of which appeared in 1964; and brood *B*, which is of little importance at present, appearing only infrequently. The greatest damage to crops occurs the year after the appearance of the adults.

Populations of white grubs can be reduced by planting deep-rooted

legumes, such as alfalfa, sweet clover, or other clovers, which are unfavorable to these insects, in rotation with more susceptible crops, such as timothy and small grains. Legumes are most effective when planted during the year the flight of the dominant brood occurs. Corn or potatoes may follow clovers in the rotation but should not follow grasses, especially in the year after a heavy beetle flight. A rotation of oats, barley, or wheat with clover and corn has proved satisfactory in some regions.

Late summer or early fall plowing destroys many larvae, pupae, and adults in the soil and also exposes these stages to predators. To be effective, the plowing must be done before the grubs go below plow depth.

Some of the natural enemies of white grubs are the vertebrate predators such as hogs, poultry, birds, and skunks. The parasitic wasps in the genera *Tiphia* and *Elis*, and *Pelecinus polyturator* Drury, and the fly, *Pyrgota undata* Wied., all destroy some grubs. The fungus parasite in the genus *Cordyceps* infects white grubs and is a factor in natural control.

When valuable crops are likely to be damaged chemical control measures should be employed. Chlordane and DDT have given satisfactory control when applied to lawns, golf courses, and soil where certain crops are to be planted, at the rate of 5 to 10 pounds of actual chemical per acre or 2 to 4 ounces per 1000 square feet. Heavier soils rich in organic material usually require the higher dosage. Heptachlor, aldrin, and dieldrin are approved for protecting lawns and various crops from grubs at dosages of 2 to 3 pounds per acre. For crops select the prescribed chemical and apply at the dosage recommended for your area. To obtain maximum effectiveness all these chemicals must be distributed below the soil surface by disking, cultivating, or washing in with water. On field crops the applications are usually made before planting, but sometimes it is advantageous to have the chemical mixed with the fertilizer and the application made at the same time the crop is being planted. On golf courses and lawns the chemical may be applied to the surface and washed in with water. Application before a heavy rainfall is appropriate. Most of these chemicals persist in the soil and prevent new infestations for several years. If control measures are thought necessary for the adults feeding on trees, a spray prepared by mixing 2 pounds of lead arsenate, 1 pound of wheat flour, and 25 gallons of water has been found successful.

References: *J. Econ. Ent.*, 31:340–344, 1938; 44:359–362, 1951; *U.S.D.A. Farmers' Bul.* 1798, 1961; *Tech. Bul.* 1060, 1953; *Home and Garden Bul.* 53, 1964.

WIREWORMS

Order Coleoptera, Family Elateridae

Wireworms are the familiar shiny, slender, cylindrical, hard-bodied, wire-like, yellow-to-brown larvae, found at all times of the year and in

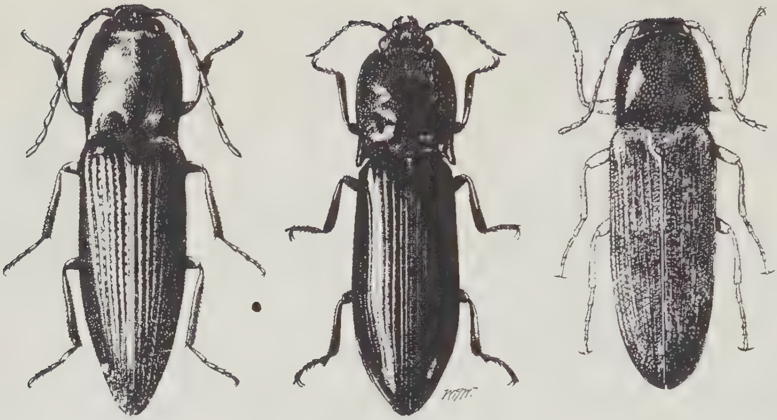


Fig. 105. Wireworm adults, from left to right: the sand wireworm, *Horistonotus uhlerii* Horn; the Great Basin wireworm, *Ctenicera pruinina* (Horn); and the eastern field wireworm, *Limonius agonus* (Say). (Walton, U.S.D.A.)

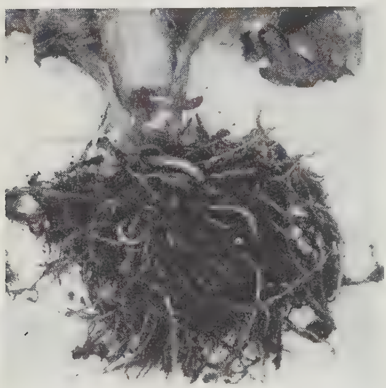
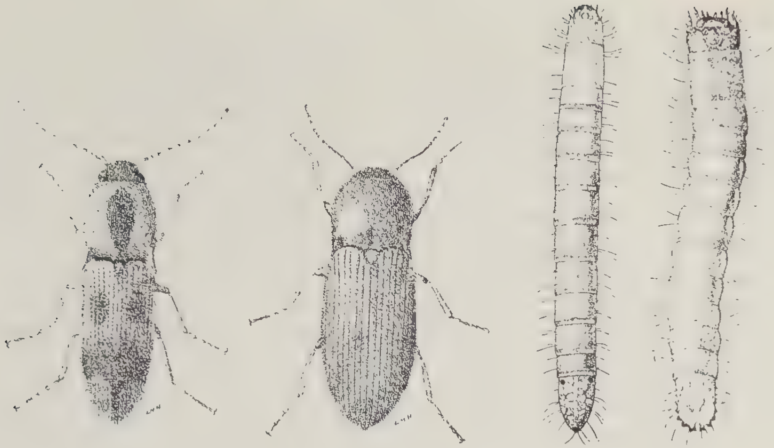


Fig. 106. Wireworm injury to roots of lettuce. (U.S.D.A.)

Fig. 107. Sugar beet wireworm, *Limonius californicus* (Mann.); injury to sprouting bean. (U.S.D.A.)

almost any kind of soil. When fully developed they vary in length from about one-half inch to one and one-fourth inches, depending on the species. Adults of these larvae are known as click beetles, so named because of the habit of snapping and flipping their bodies into the air when turned upside down. The tan-to-black beetles vary from one-fourth inch



a *b* *c* *d*

Fig. 108. Adults and larvae of wireworms: *b* and *c*, the wheat wireworm, *Agriotes mancus* (Say); *a* and *d*, a common species known as *Drasterius dorsalis* (Say). (Forbes.)

to over an inch in length, but the most common pest species are nearly one-half inch (Figs. 105 and 108).

The food plants of wireworms are many and the estimated loss to farmers because of their feeding runs into several million dollars annually. They injure crops by devouring seeds in the soil, by cutting off small underground stems and roots, and by boring in the larger stems, roots, and tubers. No crop is known to be entirely immune to their attack and such crops as grass pastures, potatoes, tobacco, onions, corn, cotton, lettuce, melons, peas, beans, cowpeas, and sugar beets are particularly susceptible (Figs. 106 and 107).

Some of the important species are the wheat wireworm, *Agriotes mancus* (Say); the sugar-beet wireworm, *Limonius californicus* (Mann.); the Pacific Coast wireworm, *L. canus* LeC.; the eastern field wireworm, *L. agonus* (Say); the western field wireworm, *L. infuscatus* Mots.; the Columbia Basin wireworm, *L. subauratus* LeC.; the sand wireworm, *Horistonotus uhlerii* Horn; the prairie grain wireworm, *Ctenicera aeripennis destructor* (Brown); the Great Basin wireworm, *C. pruinina* (Horn); the Gulf wireworm, *Conoderus amplicollis* (Gyll.); the tobacco wireworm, *C. vespertinus* (Fab.); and the southern potato wireworm, *C. falli* Lane.

Wireworms have varied life histories but many of them agree in some points. The sand wireworm and Gulf wireworm overwinter as larvae and complete their life cycles in one year; other species complete their life cycles in two to five years and overwinter as larvae or adults in the soil.

Usually the eggs are laid singly in soil 1 to 6 inches deep during the spring or early summer by either newly emerged overwintering adults, or, as with the sand wireworm, by adults which have developed from the overwintering larvae. Hatching takes place in two to four weeks, and the young larvae begin working their way through the soil in search of food. The heaviest natural mortality occurs during this early period of life because of unsatisfactory environmental conditions and lack of proper food. Little damage is caused to crops the first season from the two- to five-year species, but those which survive attain sufficient size to do considerable damage the succeeding years of larval life. There is always an overlapping of generations, wireworms of all sizes and ages being present in the soil throughout the year.

Cultural practices to reduce wireworm damage are an important phase of control. Plowing or cultivating infested soil in late summer or in autumn kills or exposes to predators the larval, pupal, and adult stages. In the irrigated areas of the Pacific Slope states regulation of the irrigation water can control wireworms. Either flooding or drying of the soil during the summer season will kill many wireworms, especially the current season's brood, thus reducing their numbers and subsequent damage. Withholding water in irrigated fields of such crops as alfalfa, which can withstand this treatment, is another way of reducing wireworm populations. Rotation of crops is also a recommended practice since continuous growing of vegetable or field crops, especially potatoes or wheat, on the same land has a tendency to increase wireworm numbers. A cropping plan, as shown in Fig. 109, is suggested for the sand wireworm. In other areas, alfalfa in the rotation is unfavorable to wireworms, and red clover and sweet clover sometimes favor wireworms. The most effective rotation system depends on the area concerned and has to be determined accordingly.

Chemicals are effective for wireworm control and the increased yields after their application often justify their cost. DDT at the rate of 10 pounds of actual chemical per acre has given successful control in the Pacific Slope states, one treatment lasting for five or more years. Some states have recommended chlordane at the rate of 3 to 6 pounds per acre or 2 to 4 ounces per 1000 square feet. On tobacco, excellent control is obtained by adding chlordane or diazinon wettable powder, or emulsifiable concentrate to the transplant water. Use 3 to 4 ounces of 50% wettable powder, or 0.25 pint of 45 to 48% emulsifiable concentrate to 50 gallons of water, and apply at the rate of 200 to 300 gallons per acre. The higher dosages should be used on heavy soils where infestations are severe. Heptachlor, aldrin, diazinon, and parathion have also been approved for wireworm control on certain crops in certain localities. Selection of the proper chemical and dosage should be made in conference with the agricultural

Two-Year Cropping Plan

First-year planting			Second-year planting	
November to late February or early March	March to July 10	July 10 to October	November to late February or early March	March to September
Winter Cover	Spring	Summer	Winter Cover	Main Crop
Oats or rye	Grain followed by stubble	Cover crop, hay, or sweetpotatoes	Austrian winter peas or vetch	Cotton or corn

Three-Year Cropping Plan

First-year planting			Second-year planting		Third-year planting	
November to late February or early March	March to July 10	July 10 to October	November to late February or early March	March to September	October to February or March	March to October
Winter Cover	Spring	Summer	Winter Cover	Main Crop	Winter Cover	Spring
Oats or rye	Grain followed by stubble	Cover crop, hay, or sweetpotatoes	Austrian winter peas or vetch	Cotton or corn	Austrian winter peas or vetch	Velvetbeans, tomatoes, or early watermelons

Fig. 109. Cropping plans for reducing the damage done to crops by the sand wireworm. The 2-year plan is for land having a heavy wireworm infestation, and the 3-year plan is for land having a wireworm infestation known to be light. (U.S.D.A.)

specialists in your area. To be effective all chemicals must be mixed well with the top several inches of the soil. They will all persist in the soil and give several years' protection.

Control by seed treatment contributes to the establishment of young seedlings, but it does not insure that the subsequent plant stems and tubers will not be attacked later in the season. Dosage is usually an ounce of actual chemical per bushel of seed and the prescribed formulation is wettable powder. Seed treatment is most effective on the large acreages of small grains grown under dry-land conditions of western United States and Canada, where any other soil treatment would be too expensive.

Soil fumigation has been adopted in irrigated areas of the West Coast. An 83% solution of ethylene dibromide applied at 3 to 5 gallons per acre has given good immediate wireworm control. Special machinery has been developed for applying this material to a depth of about 8 inches. The soil should be plowed and disked as deeply as possible before application is made. Dragging a heavy chain or iron bar behind the injection machine retards the escape of the fumigant. This chemical retards germination of seeds and has an adverse effect on most plants. For these reasons do not

set transplants or sow seeds until 21 days after fumigation. Treat soil no closer than 10 feet to fruit trees or 3 feet to small trees and shrubs.

References: *U.S.D.A. Farmers' Bul.* 2220, 1966; *Leaflet* 212, 1941; 534, 1965; E-765, 1948; E-786, 1949; EC-6, 1948; EC-19, 1951; *Farmers' Bul.* 2040, 1952; *Tech. Bul.* 1172, 1958; *J. Econ. Ent.*, 29:288–296, 1936; 38:643–645, 1945; 45:548–549, 1952; 46:1075–1083, 1953; 51:690–692, 1958; *Canada Dept. Agr. Pub.* 942, 1955; 979, 981, 1956.

FALSE WIREWORMS

Order Coleoptera, Family Tenebrionidae

False wireworms range from Canada to Texas but are more commonly found in the drier wheat-growing areas of the region between the Mississippi River and the Pacific Coast. Wheat is a favored host plant, but other grasses, cotton, legumes, sugar beets, and garden crops may be attacked. The sprouting seeds and young seedlings are eaten by the larvae, and the adult beetles eat various plants above ground but to a lesser degree. The greatest damage occurs in the fall of the year.

Species causing damage are *Eleodes opacus* (Say), *Eleodes suturalis* (Say), *E. tricostata* (Say), *E. hispilabris* (Say), *Blapstinus substriatus* Champion, and *Embaphion muricatum* Say. Populations fluctuate considerably; these insects are usually of minor importance.

The dark or black adults, called darkling beetles, resemble ground beetles in general aspect and measure scarcely 1 inch in length. The larvae resemble wireworms in shape and coloration but can be distinguished from them by the prominent, thickened antennae and very large front legs (Fig. 110). False wireworms are also more active than wireworms.

Fig. 110. *Eleodes opacus* (Say), a false wireworm and adult. (McColloch, Kansas Agr. Exp. Sta.)

The life cycles of the different species vary to some extent. *Eleodes opacus* has a one-year cycle; *E. hispilabris*, in the Pacific Northwest, may require as long as 2 years. The eggs are laid in late summer and fall, and the most active feeding period of the larvae is immediately after hatching, so that severe damage occurs in autumn. The partly grown larvae overwinter, pupate in the spring, with adult emergence continuing over a period of several weeks. The overwintering stage may also be the adult since they live for as long as three years.

The control measure commonly practiced is to follow a rotation so that corn or other cultivated crops occur for two years between plantings of wheat. Should a severe infestation develop, many of the chemicals recommended for application against the wireworms and white grubs will give satisfactory control.

ARMYWORM

Pseudaletia unipuncta (Haw.), Family Noctuidae

The armyworm is a caterpillar which, in seasons of unusual abundance, crawls in large numbers from field to field devouring grasses and grain crops. Wheat, corn, oats, and rye are among its favored food plants. Outbreaks are more common following cold, wet, spring weather, and damage may occur from late April to late June. It occurs throughout most of the United States east of the Rocky Mountains, and it has also been found in New Mexico, Arizona, California, and Canada.

The buff or sand-colored moth has a wing expanse of about $1\frac{1}{2}$ inches with a small white dot in the center of each fore wing and somewhat darker margins on the hind wings (Fig. 111). The dot is a convenient recognition mark and the basis for the specific name. Adults feed on the nectar of flowers. The full-grown larva is a nearly naked, smooth, striped

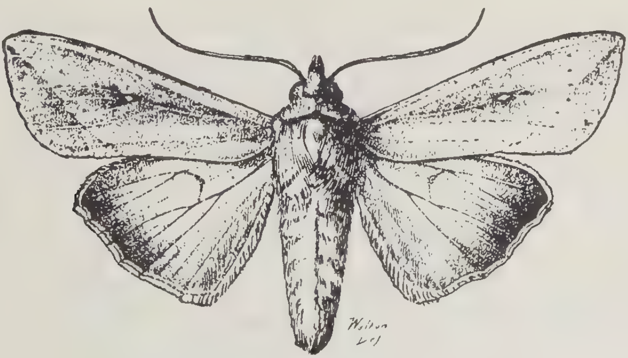


Fig. 111. The armyworm moth, *Pseudaletia unipuncta* (Haworth). (U.S.D.A.)

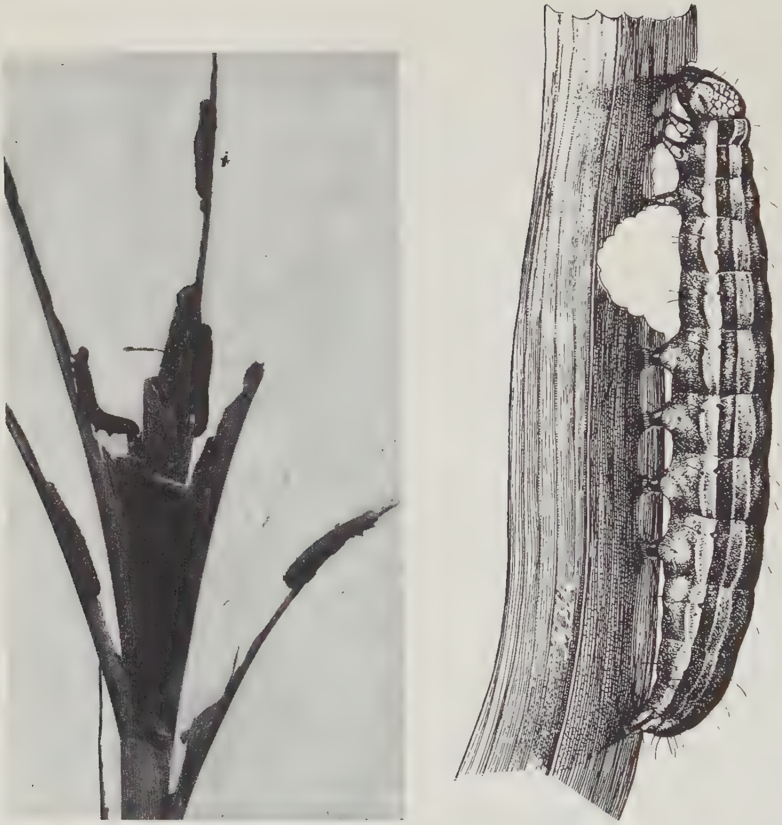


Fig. 112. (Left) armyworms feeding on corn. (Slingerland). (Right) the same, much enlarged. (U.S.D.A.)

caterpillar, about $1\frac{1}{2}$ inches long. Its general color is green to brown, and the stripes, one along each side and a broad one down the back, are dark and often nearly black. The stripe along the back usually has a fine, light-colored, broken line running down its center. The head is pale brown with a green tinge and mottled with dark brown (Fig. 112).

Partly grown caterpillars hibernate in the soil or debris at the surface and complete their growth in the spring. In the latitude of central Ohio pupation takes place the latter part of April, and about two or three weeks later adults emerge and lay eggs. The moths are attracted to lights at night, and their relative numbers may serve as an indication of probable larval abundance. The eggs are laid in large masses at night, usually in the folded blades or under the leaf sheaths of grains and grasses. They resemble small white beads, each smaller than the head of a common pin. Many

moths seem to congregate and lay their eggs in the same locality. In eight to ten days tiny greenish caterpillars hatch from the eggs and begin feeding. This is the first generation of larvae and it usually causes the most damage. After molting several times they become fully grown in about three or four weeks, then pupate and emerge as adults. There are usually three generations of caterpillars each year in the northern states but seldom two successive outbreaks in any given locality. Some evidence indicates that all stages may be present during the winter in the extreme South.

One of the important natural enemies of the armyworm is *Winthemia quadripustulata* (Fabr.), commonly called the red-tailed tachina fly (Fig. 113). It oviposits on the caterpillars, and its larvae bore into the body and devour the inside portions. The flies multiply rapidly and often become numerous enough to completely control the armyworm in a given locality.

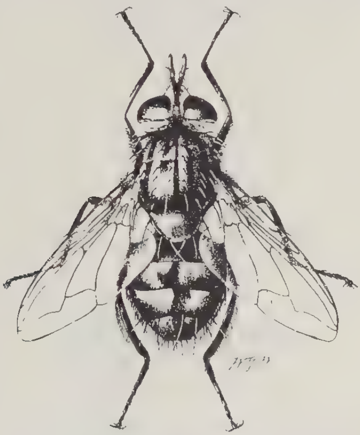


Fig. 113. *Winthemia quadripustulata* (Fabr.), one of the most important armyworm parasites. (Walton, U.S.D.A.)

A braconid wasp, *Apanteles militaris* (Walsh), also plays an important role in natural control. Other natural enemies are the ground beetles, sphex wasps, birds, toads, skunks, and domestic fowls.

Insecticides are helpful when natural enemies do not keep it in check. The following insecticides are reported to be satisfactory: carbaryl, chlordane, DDT, TDE, methoxychlor, Dylox, malathion, parathion, and toxaphene. Selection of the appropriate chemical will depend on the crop to be protected and the area in which the outbreak of armyworms occurs.

Poisoned baits, as recommended for grasshopper control, have also given successful kill of armyworms. A standard bait consists of 100 pounds of bran, 2 gallons of molasses, 4 pounds of paris green, white arsenic, or sodium fluosilicate, and approximately 10 gallons of water. These ingredients should be thoroughly mixed and scattered along the line of march in late afternoon or evening. The quantity given treats about 5 acres.

All the chemicals recommended are poisonous to man and other animals, so care should be exercised in their use.

References: *U.S.D.A. Farmers' Bul.* 1850, 1947; *leaflet* 494, 1961; *J. Econ. Ent.*, 44:542–551, 1951.

FALL ARMYWORM

Spodoptera frugiperda (Smith.), Family Noctuidae

The fall armyworm is essentially a southern insect which extends its attacks during some seasons to a large portion of the United States. It migrates northward each year and sometimes becomes abundant in the northern states but only in late summer and fall. Other areas in which it is found are Central and South America.

Food plants are much more varied than those of the true armyworm. Known mainly as a pest of corn it also feeds on cotton, alfalfa, clover, peanuts, grasses, tobacco, and many garden crops. The damage results when the larvae devour plant parts above ground. The shanks and ears of corn are often extensively damaged by the larvae boring inside them. It is probably of greater importance as a pest than the true armyworm which it somewhat resembles in habits and general appearance.

The eggs are laid at night on grasses or other plants in masses of as many as a hundred or more. These hatch into larvae in two to ten days, molt six times before becoming fully grown in about twenty days, and enter the soil and transform to pupae. The inactive pupal stage lasts about ten days, after which the adult moths emerge and often migrate many miles before the females lay their eggs. In its northern range there are one or two generations per year, whereas in the South there may be several. None of the life stages survive the winters in the North; in the South all stages may be present but are more or less inactive in areas where no freezing temperatures occur. When abundant, and the food supply becomes exhausted, the larvae migrate as do true armyworms. The larvae have a prominent, white inverted Y-shaped suture on the front of the head and longer hairs arising from black tubercles on the body, which are more conspicuous than those on the true armyworm. The adults resemble cutworm moths, having dark gray fore wings mottled with light and dark spots and grayish white hind wings (Fig. 114).

Besides the effects of climatic factors on the abundance of fall army-

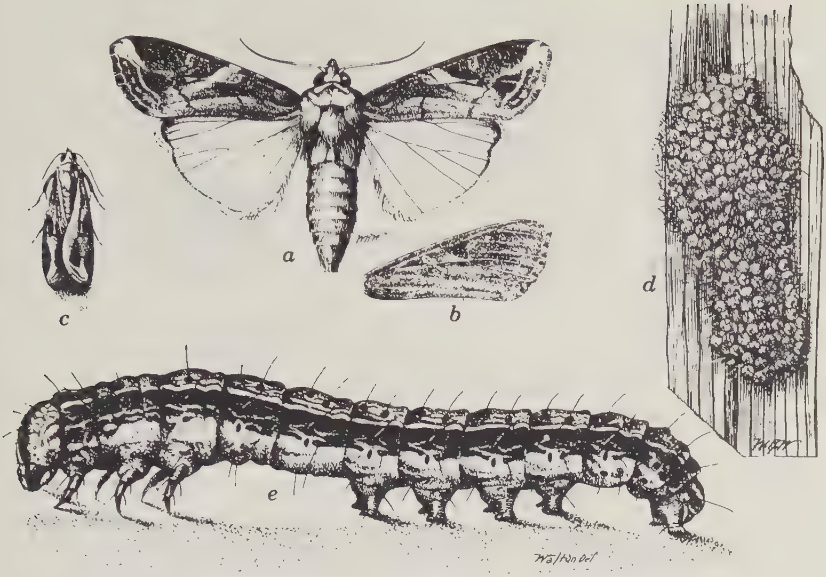


Fig. 114. The fall armyworm: *a*, ♂ moth; *b*, right front wing of ♀ moth; *c*, ♂ moth in resting position; *d*, egg mass; *e*, larva. (Walton, U.S.D.A.)

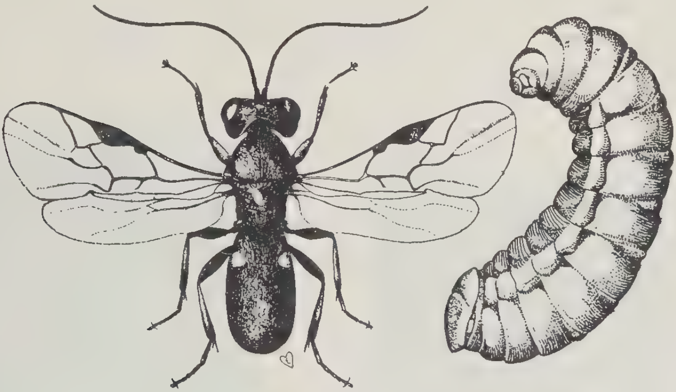


Fig. 115. *Chelonus texanus* Cresson, an important parasite of the fall armyworm. (Walton and Luginbill, U.S.D.A.)

worms, the parasitic enemies are numerous and greatly reduce the populations. Some of these parasites are the ichneumon wasp, *Ophion bilineatus* Say; the braconid wasps, *Chelonus texanus* Cress. (Fig. 115), *Meteorus laphygmae* Vier., and species of *Apanteles;* the egg parasite, *Trichogramma minutum* Riley; a chalcid wasp in the genus *Euplectrus;* and the tachina

flies, *Winthemia quadripustulata* (Fabr.) and *W. rufopicta* (Bigot). Predators include ground beetles, birds, and vertebrate enemies of caterpillars of all types.

All the chemicals at the dosages indicated for controlling armyworms (p. 147) have proved effective in killing fall armyworms. In addition to these, diazinon and Strobane are also recommended. Choice of the proper chemical depends on the crop to be protected and the hazards involved in its use. Follow the control recommendations published for your area.

References: *U.S.D.A. Tech. Bul.* 34, 1928; *Tech. Bul.* 138, 1929; *Leaflet* 494, 1961; *J. Econ. Ent.*, 42:502–506, 1949.

CUTWORMS

Order Lepidoptera, Family Noctuidae

Larvae that cut off low-growing plants at, or slightly below, the surface of the soil, are called cutworms. Species that feed above ground on any part of the plant are called climbing cutworms (Fig. 116). Fruit trees and many other plants are sometimes injured by these species. When a high population develops and the food supply becomes exhausted, migration to other plants takes place as with armyworms. These species are sometimes called army cutworms (Fig. 117). Some species are more specific than others as to the hosts on which they feed. Our common cutworms are most injurious to garden vegetables, corn, cotton, tobacco, and similar crops grown in rows or hills, whereas small grains and forage crops are damaged to a lesser extent.

Fig. 116. Climbing cutworms. (Mich. Agr. Exp. Sta.)

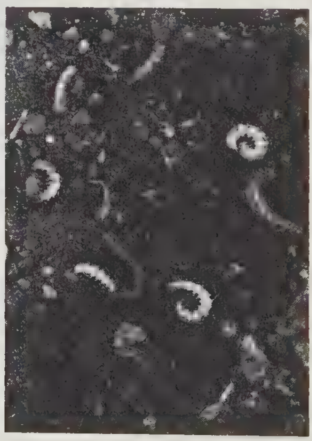


Fig. 117. The army cutworm. (Dean, Kansas Agr. Exp. Sta.)

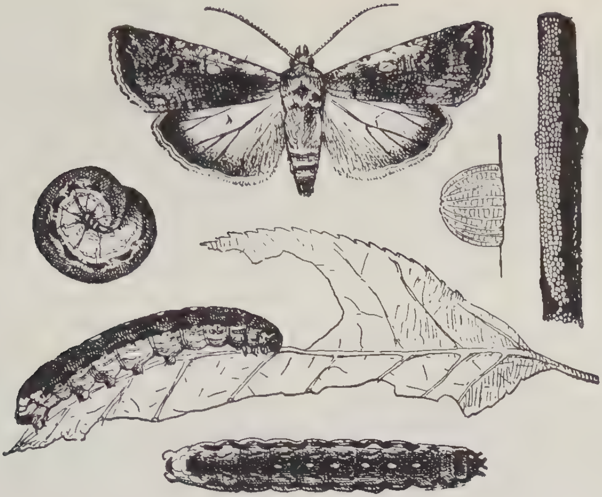


Fig. 118. Life stages of the variegated cutworm, *Peridroma saucia* (Hübner). (Howard, U.S.D.A.)

Some better-known cutworms are the following: the black cutworm, *Agrotis ipsilon* (Hufnagel); the dingy cutworm, *Feltia subgothica* (Haworth); the clay-backed cutworm, *F. gladiaria* (Morrison); the granulate cutworm, *F. subterranea* (F.); the bronzed cutworm, *Nephelodes emmedonius* (Cramer); the variegated cutworm, *Peridroma saucia* (Hubner) (Fig. 118); the spotted cutworm, *Amathes c-nigrum* (L.); the army cutworm, *Chorizagrotis auxiliaris* (Grote); the pale western cutworm, *Agrotis orthogonia* Morrison; the glassy cutworm, *Crymodes devastator* (Brace); the bristly cutworm, *Lacinipolia renigera* (Steph.); the red-backed cutworm, *Euxoa ochrogaster* (Guenée); the dark-sided cutworm, *E. messoria* (Harris); the striped cutworm, *E. tessellata* (Harris); and the black army cutworm, *Actebia fennica* (Tausch.).

The adults of all cutworms are moths with dark gray fore wings, often variously marked with darker or lighter spots and narrow bands, and lighter colored hind wings (Fig. 119). When at rest the wings are folded over the back. They feed at dusk by sucking nectar from flowers, and are often attracted to lights at night. The moths lay many hundreds of eggs, and most of these are on plants in grassy sod or weedy fields. On hatching, the larvae molt several times and when fully grown are nearly 2 inches long. They then tunnel into the soil where they form cells in which pupation occurs. The moths emerge from the pupae and crawl out of the ground through the tunnels made by the larvae. The time required to complete the life cycle varies with the different species. The glassy, army,

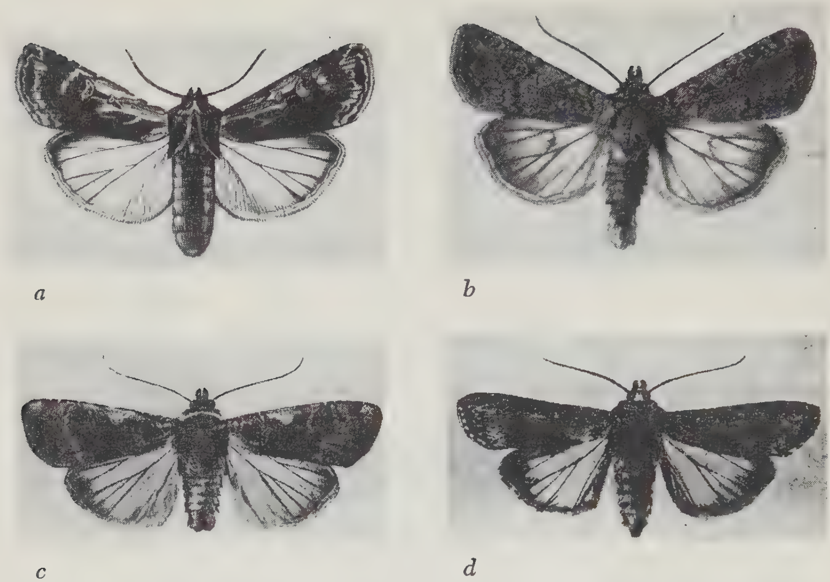


Fig. 119. Common cutworms: *a*, the granulate cutworm, *Feltia subterranea* (F.); *b*, the dark-sided cutworm, *Euxoa messoria* (Harr.); *c*, the spotted cutworm, *Amathes c-nigrum* (L.); *d*, the black cutworm, *Agrotis ipsilon* (Hufnagel). (U.S.D.A.)

dingy, bronzed, and black army cutworms overwinter as partly grown larvae and have one generation per year. The pale western cutworm overwinters as an egg with one generation per year. The black cutworm overwinters as a larva or pupa and has two generations in Canada and several in southern United States. The spotted and variegated cutworms have two to four generations per year and overwinter as larvae or pupae.

Greatest injury from one-generation cutworms results from the spring feeding of those species wintering as larvae. If grassy sod land or weedy fields are plowed in the spring, the food supply of the cutworms present is greatly reduced, and, if this soil is then prepared and set to such plants as tomato, tobacco, or cabbage, serious damage usually follows. Damage at other times in the summer occurs with species having two or more generations per year, or with overwintering stages other than larvae.

Natural and applied control measures for cutworms are very similar to those given for armyworms (p. 147). Where they fit into the general farming practices, cultural control methods are of value. For instance, land kept free of weeds and crops during late summer is rarely infested; various life stages may be destroyed by fall plowing; cultivation of infested fields in the spring after vegetation has appeared in them and has grown

to a height of 2 inches followed by seeding, deferred at least ten days, results in starvation of many larvae; a rotation in which hill or row crops do not follow a grassy sod is also a means of avoiding damage.

Chemical control is often necessary to protect crop plants. The following are approved chemicals for cutworm control: carbaryl, chlordane, diazinon, DDT, Dylox, TDE, malathion, naled, parathion, Phosdrin, Strobane, and toxaphene. Selection of the proper chemical for use on a particular crop should be made with the help of your local agricultural specialist. Toxicity and persistence of the chemical residue should be considered. Keep in mind that these insecticides act largely through contact with the insect and are more effective if their application is restricted to a narrow band near the plants on both sides of row crops, or uniformly distributed and harrowed in the top few inches of the soil for other crops. Poisoned baits, as described for grasshoppers (p. 133) and armyworms (p. 148), also give satisfactory control. Baits should be distributed in the evening near the plants to be protected. Avoid baiting where poultry and other domestic animals might be poisoned.

References: *Mont. Bul.* 225, 1930; *Can. Bul.* 59, 1938; *Tenn. Exp. Sta. Bul.* 159, 1936; *J. Econ. Ent.*, 41:631–635, 1948; 54:250–252, 1961; 56.219–221, 1963; *U.S.D.A. Tech. Bul.* 88, 1929; *Leaflet* 417, 1957.

STALK BORER

Papaipema nebris **(Guen.), Family Noctuidae**

The stalk borer is widely distributed east of the Rocky Mountains. Its larvae feed on a great variety of plants, especially the stalks of corn, cotton, potato, tomato, dahlia, hollyhocks, tiger lilies, tobacco, and giant ragweed. The damage is done primarily by boring and tunnelling in the stalks. Cultivated crops adjacent to weedy areas of the favorite host, giant ragweed, are most often attacked.

The moth is fawn gray or mouse-colored, with the outer third of the fore wings paler and bordered within by a white cross line. Two clusters of white spots, which are variable in distinctiveness, appear on the darker two thirds of the fore wings (Fig. 120). The spots in the fore wings are obscured in the variety *nitela.* The hind wings are grayish brown to smoky for both *nebris* and *nitela.* The appearance of the larva in its earlier instars is purplish to light brown with five white stripes, one along the middle of the back and two on each side. These side stripes are absent on the first four segments of the abdomen, giving the larva an appearance of having been injured. The last instar is light in color and only faintly striped.

The overwintering eggs are laid on the leaves of the host plants during late summer and early fall. They hatch the following May or June and

Fig. 120. The stalk borer, adult, (right) and larvae, (left).

the larvae pass through seven to sixteen instars, most of them completing their development in seven to nine. Pupation takes place in the soil or the larval burrows in plants; the moths emerge in late August and September and deposit their eggs, completing the life cycle. Only one generation occurs each year.

Climatic conditions, birds, mammals, insect predators and parasites, and diseases are all responsible for reducing the numbers of this insect.

Applied control measures consist of destruction of the weeds which harbor the larvae or eggs by deep plowing or burning. Mowing weeds along fence rows in late August renders the locality undesirable for oviposition and in turn reduces the population in such areas the following season. Should chemical control be necessary, those recommended for armyworms (p. 147) are suggested for this insect.

Reference: *Iowa Res. Bul.* 143, 1931.

SOD WEBWORMS OR GRASS MOTHS

Crambus spp., Family Pyralidae

Sod webworms are widely distributed throughout the United States and Canada. They become important pests of grassland, lawns, golf courses, and occasionally cultivated crops, such as corn or tobacco, planted in soil which was previously a grassy sod. The varied yellow-to-white larvae spin silken threads as they crawl about and feed, webbing the soil particles and leaves together near the surface, often forming silken tubes within which they live. Most of the damage results from their feeding at the soil surface or slightly below (Fig. 121). The pale brown moths vary from $\frac{1}{2}$ to $\frac{3}{4}$ inch in length, hold their wings tightly over the body when at rest, and the labial palpi project forward from the head, forming a snout, which is the basis for another suggested common name, the snout moths.

Fig. 121. Work of the corn root webworm.

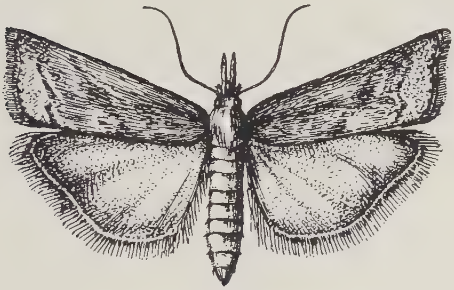


Fig. 122. The adult of the corn root webworm, *Crambus caliginosellus* Clemens. (U.S.D.A.)

Some of the more common species are: the corn root webworm, *Crambus caliginosellus* Clemens; the bluegrass webworm, *Crambus teterrellus* (Zincken); the vagabond crambus, *Crambus vulgivagellus* Clemens; the larger sod webworm, *Crambus trisectus* Walker; the striped sod webworm, *Crambus mutabilis* Clemens; the silverstriped webworm, *Crambus praefectellus* Zincken, and *Crambus topiarius* Zeller (Figs. 122 and 123).

The usual overwintering stage is larvae in cases of silk covered with soil particles near the ground level or slightly below. They feed in the spring, becoming fully grown after passing through seven to twenty

Fig. 123. Sod webworms. Above, left to right, *Crambus vulgivagellus* Clemens, the vagabond crambus, and *C. mutabilis* Clemens, the striped sod webworm; below, the bluegrass webworm, *C. teterrellus* (Zincken), and the silver-striped webworm, *C. praefectellus* Zincken. (Ainslie, U.S.D.A.)

instars. This is followed by pupation close to the feeding tunnels inside cocoons, which are lined with soft gray silk and covered with soil and grass particles interwoven with silk. Adult moths appear in the summer months, the females at dusk, dropping their eggs over grassy areas while either in flight or at rest. These eggs hatch in about seven days and the larvae begin the cycle anew. The corn root webworm has only one generation per year; the bluegrass webworm has two or three, and the larger sod webworm normally has two, but a partial third generation may occur at its southern limits of distribution.

Natural enemies include many vertebrate and insect predators, a number of dipterous and hymenopterous parasites, as well as some pathogenic diseases.

Rotation of crops so as to avoid planting corn on soil that had been in grass sod the previous year, ample fertilization, early fall plowing to prevent egg deposition in the field, or later fall plowing followed by cultivation to kill overwintering larvae are cultural and mechanical control measures.

Chemical control is now practical, especially on lawns and golf courses. Summer treatment should be initiated when dead, irregular, brown spots appear in the lawn. Apply chlordane at the rate of 2 to 3 pounds per acre. For small areas this would be 3 pounds of 5% chlordane dust per 1000 square feet, or 1 teaspoonful of 45 to 48% emulsifiable concentrate, or 3 level tablespoonfuls of 50% wettable powder in 1 gallon of water per 100 square feet. Water the lawn thoroughly before treatment, and do not

water again for several days. Other chemicals equally effective are: aldrin, heptachlor, carbaryl, ethion, Dursban, diazinon, DDT, and toxaphene. Follow the directions on the package label.

References: *J. Econ. Ent.*, 45:114–118, 1952; 52:966–969, 1959; 53:670–672, 1960; 57:41–42, 150–152, 1964; *U.S.D.A. Home and Garden Bul.* 53, 1964; *Proc. N.C. Branch Ent. Soc. Amer.*, 18:72, 1963.

9

Insects Injurious to Grasses and Cereal Grains

This chapter contains a description of the major insect enemies of corn, wheat, oats, rye, barley, rice, sugarcane, and sorghums. Many of these crops are essential the world over as a source of food for man and other animals. Although control has been difficult in the past, recent research with new chemicals has resulted in insecticides that are highly effective.

CORN EARWORM

Heliothis zea **(Boddie), FAMILY NOCTUIDAE**

Corn earworm is cosmopolitan and considered to be one of the half-dozen most destructive insects attacking corn, especially sweet corn. Its range in the United States is almost coincident with that of the corn plant, although in the northern part of the corn-growing area the insect may be very rare. Because of high winter mortality north of 39° N. latitude it is not a permanent resident throughout its range but migrates from the South and reinfests northern areas each year.

Besides corn, it is an important pest of cotton and is then called the bollworm. On tomatoes it is known as the tomato fruitworm. Some other hosts are beans, alfalfa, clover, vetch, and tobacco.

Damage to corn results when the larvae feed in the tips of the ears, devouring the kernels and fouling them with excrement, sometimes destroying the silks before pollination is completed. Rarely do the larvae bore through the cob or husks like the European corn borer, entrance being made through the silk channel. Secondary loss, from molds which follow the feeding of the worms, is often extensive. Injury to tomatoes, cotton bolls, and bean pods is caused by the larvae boring through these plant parts. Foliage of these and other hosts is often eaten.

In the areas where this insect survives the winter, brown pupae hibernate in the soil. Moths having a wing expanse of about $1\frac{1}{2}$ inches emerge in February for the Gulf Coast states and in June for 39° N. latitude.

The moths are light buff with irregular darker lines and spots near the outer margins of the fore and hind wings (Figs. 124 and 125). They fly at dusk and deposit their eggs on the corn silks and other parts of the plant. Each female moth may deposit 1000 or more eggs during her life span. Hatching occurs a few days later, and the larvae feed downward through

Fig. 124. Corn earworm moths and larva. (U.S.D.A.)

the silks into the ear tip, become fully grown in about three or four weeks, then leave the ear and enter the soil forming a cell in which pupation takes place. Fully grown larvae are about $1\frac{1}{2}$ inches long, variable in color ranging from light green through brown to almost black, with light and dark stripes running lengthwise of the body which is lighter on the underside. Development from egg to adult requires about thirty days in midsummer and a longer period in early spring or late autumn. Usually two generations develop in the North, with as many as five or six in the extreme South.

Natural control results from cannibalism of the larvae, the egg parasite, *Trichogramma minutum* Riley, the larval parasite, *Winthemia quadripustulata* (Fabr.), the predatory bug, *Orius insidiosus* (Say), and a number of other predaceous insects and birds.

Injury to both field and sweet corn can be reduced by growing strains with long tight husks which extend beyond the tips of the ears. Earworm-resistant sweet corn varieties also show promise. Planting at a time that

results in the corn silking between the two generations in the northern range averts damage. In the areas where overwintering occurs, usually early- or late-planted sweet corn suffers the greatest damage. Fall or spring plowing and disking of the soil reduces the number of moths that emerge in the spring from overwintering pupae. This operation has some

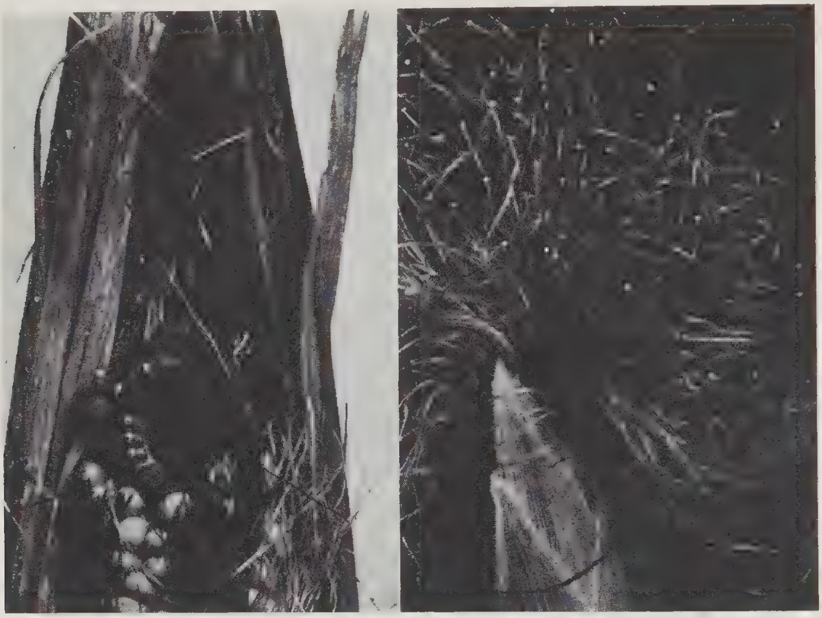


Fig. 125. Earworm at work near tip of ear; typical injury, and eggs on silks. (Quaintance and Brues, U.S.D.A.)

control value if done on a community-wide basis. The infestation is reduced by clipping the silks, including about an inch of the husks, after pollination is completed. The clippings must be removed from the field.

Usually no chemicals are applied to control corn earworm in field corn, but they are widely used on sweet corn. Approved chemicals are carbaryl, DDT, and diazinon. Emulsion sprays of DDT have been more widely used. Mix 4 quarts of a 25% DDT emulsifiable concentrate with water to make 25 gallons and apply this quantity per acre. Direct the spray to the silks about one day after 7 to 10% of the ears are silking, with repeat applications about two or three days apart. For a smaller quantity of spray use $\frac{1}{4}$ pint of the DDT concentrate with water to make 1 gallon. This will cover a plot about 17 by 100 feet.

Because of poisonous residues the husks and other parts of corn plants treated with DDT must not be fed to livestock. Corn treated with car-

baryl at 1 to 2 pounds per acre or diazinon at 1 to $1\frac{1}{4}$ pounds per acre can be fed to livestock two days after the last application.

A compressed-air hand sprayer is satisfactory for treating garden plots of sweet corn; for large commercial plantings high-clearance power sprayers, adjusted to give coverage of the ears and silks, are required. Dusts can be applied with a stencil brush or hand duster where garden plantings become infested with earworms.

An older but effective method of earworm control in small plantings of sweet corn consists of injecting into the silk channel at the tip of the ear about 0.75 ml. of mineral oil (120 to 125 seconds Saybolt viscosity) containing 0.2% pyrethrins or 0.5 to 1% DDT or DDD. Make applications when the silks have wilted and begun to turn brown at the edges with a pump-type long-spouted oil can or a glass medicine dropper properly calibrated. Earlier treatment interferes with proper pollination and results in poorly filled ears.

For control on flowers, dusts containing 5% carbaryl, DDT, chlordane, or toxaphene are recommended.

References: *U.S.D.A. Farmers' Bul.* 1651, 1953; *Leaflet* 411, 1961, *Tech. Bul.* 561, 1937; *Tech. Bul.* 1160, 1957; *Tech. Bul.* 838, 1942; E-780, 1951; *J. Econ. Ent.*, 41:928–935, 1948; 45:105–108, 137–138, 931–933, 1952; 52:1111–1114, 1959; 53:22–24, 1960.

EUROPEAN CORN BORER

***Ostrinia nubilalis* (Hbn.), Family Pyralidae**

It is thought that the corn borer was introduced into the United States about the year 1909 in shipments of broom corn from Europe, where it had long been known as a pest of corn and other crops. However, the first record of its presence was in Massachusetts in 1917. It has since spread to practically all the major corn-producing areas of the United States and Canada, and yearly losses estimated to be as high as 314 million bushels of field corn have been reported. Early plantings of sweet corn are often a complete loss in years of corn borer abundance.

The major host is corn, with some indication that sweet corn is the favorite kind. Other hosts are chrysanthemum, dahlia, gladiolus, eggplant, pepper, beet, bean, potato, tomato, oat, soybean, and many kinds of weeds.

Damage to corn is caused by the early larval instars chewing the leaves, resulting in destruction of the leaf surface and midrib breakage. Later instars tunnel all parts of the stalks and ears, resulting in broken stalks and tassels (Fig. 126), poor ear development, and dropped ears. Other hosts are damaged primarily by the tunnelling of the stalks or stems by the larvae. The first indication of the presence of the borers is leaf damage, followed by larval borings protruding from holes in the stalks.

Fig. 126. Cornstalks badly injured by the European corn borer. (U.S.D.A.)

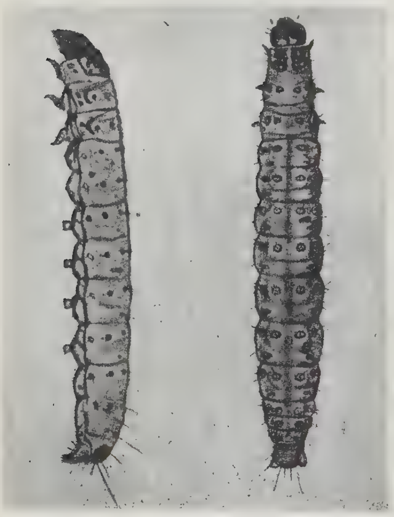


Fig. 127. Side and dorsal views of the European corn borer larva. (U.S.D.A.)

Fig. 128. European corn borer egg mass about to hatch. (U.S.D.A.)

The borers pass the winter as fully grown larvae concealed in parts of the plants on which they have been feeding. They are flesh-colored, $\frac{3}{4}$ inch in length, and marked with brown spots (Fig. 127). Pupation takes place in late spring, with the adult moths appearing in June. The moths are buff-colored, with dark brown wavy bands across the wings and a wing expanse of about 1 inch. The male is smaller in size and darker in color (Fig. 129). They mate and the females begin laying white eggs, in masses of fifteen to thirty-five, on the undersides of the lower leaves of the host plants.

The tallest, earliest maturing varieties of corn receive the greatest number of eggs. Each female may lay 500 or more eggs during her life span. These overlapping scalelike eggs (Figs. 128 and 130) hatch in about seven days, and the black heads of the young larvae can be seen inside

Fig. 129. The European corn borer, *Ostrinia nubilalis* (Hbn.); (left) female; (right) male. (U.S.D.A.)

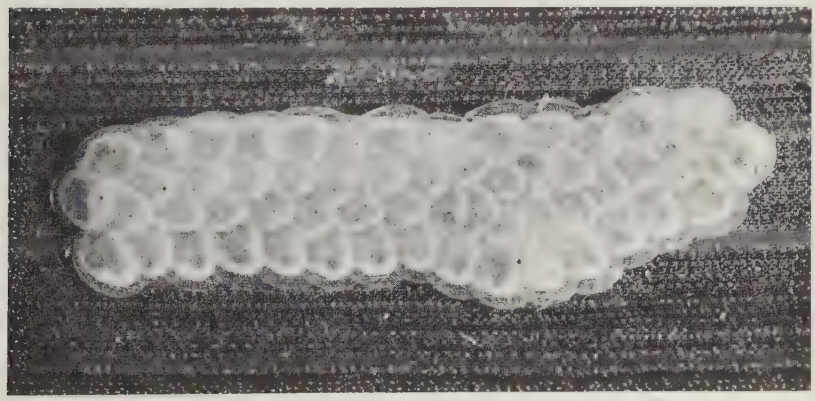


Fig. 130. Newly deposited egg mass of the European corn borer, greatly magnified. (U.S.D.A.)

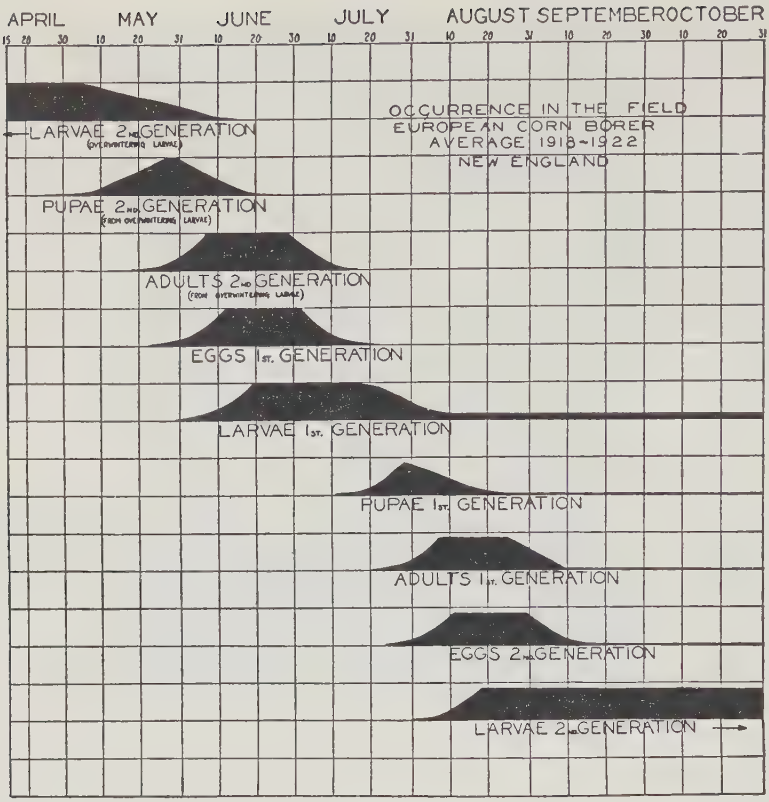


Fig. 131. Seasonal occurrence of the European corn borer in New England. Averaged from data obtained during the period 1918 to 1922, inclusive. (Caffrey and Worthley, U.S.D.A.)

before hatching. The larvae feed at first on the leaves, and then the leaf sheath and whorl, often causing evident damage to the unfolding tassel. They are fully grown in approximately thirty-five days and, if they are of the one-generation-per-year strain, will remain as larvae until the following spring. If they are of the two-generation strain, pupation takes place, new adults emerge in July and early August and lay eggs, beginning a new generation (Fig. 131). These hatch, and larval damage occurs through August and September. When fully grown they pass the winter in that stage. The percentage of first-generation larvae that pupate, emerge as adults, and produce the second generation is variable in different latitudes of the corn belt but generally increases from North to South. The cause of this variation or diapausing condition of some larvae is correlated with temperature and photoperiod (sunrise to sunset). Mid-

summer pupation of corn borer larvae under field conditions is closely associated with length of photoperiod. Borers reaching maturity after photoperiods shortened to less than 14.75 hours tend to enter a state of diapause. This length of photoperiod occurs at Madison, Wisconsin, on July 25. Pupation occurred if borers attained the fifth instar before this date. Prolonged periods of high temperature before this date increased pupation, whereas periods of low temperature reduced pupation and increased the number of diapausing larvae.

Cool, rainy weather during the month of June greatly reduces the infestation of borers because it inhibits oviposition and washes the tiny hatching larvae from the plants. Very dry summers and extremely cold winters also are unfavorable to borer development and survival.

Some degree of biological control has been achieved with the tachina fly, *Lydella thompsoni* Herting. Other insect parasites of some value are *Macrocentrus gifuensis* Ashm., *Horogenes punctorius* (Roman), and *Chelonus annulipes* Wesm. A protozoan parasite, *Perezia pyraustae* Pail., was found widely distributed in hibernating larvae. It also infects other life stages, retarding female oviposition and larval development. The fungus, *Beauvaria bassiana* (Bals.), also kills corn borers.

Planting borer-resistant or tolerant hybrid varieties of corn adapted for particular areas is a recommended cultural practice. Consult the state extension service for its recommendations. Some hybrids resist stalk breakage and ear dropping under light-to-medium borer infestation and are therefore harvested more easily. Avoiding very early or very late planting keeps the borer infestation at a low level. In the latitude of Ohio, planting between May 12 and 25 is recommended. Later planted corn may be severely damaged by the second-generation larvae. Mechanical destruction of stalks and stubble to kill overwintering larvae is of little value unless carried out on a community-wide basis, and even then it is questionable. Plowing is the suggested method for eliminating these crop remnants which harbor borers. The larvae in infested corn cut for silage or fodder are destroyed by the silage cutter or the husking and shredding machines. All these control measures are of value, but the cultivation of resistant hybrids and planting at the proper time are especially important, and in most years are all that is needed to keep damage at a low level in field corn.

The need for chemical treatment is determined by the value of the crop and the intensity of infestation. Early sweet corn or hybrid seed corn plantings usually compensate for the increased costs of chemicals and their application. One or two treatments are recommended for early-planted field corn of a susceptible hybrid when examination in the field reveals that 75% of the plants have new larval feeding marks in the

whorls. In the two-treatment schedule, the first is made one week after egg-hatching begins and the second a week or ten days later. The single application is recommended ten to twelve days after first hatching occurs. If there are 100 egg masses per 100 plants, treatment should be made when hatching begins. Sweet corn should be treated when 25% of the plants show larval feeding marks or if twenty or more egg masses per 100 plants are found on corn one week before tasselling, or 50 or more egg masses per 100 plants for corn fourteen to twenty days before tasselling. Make three or four applications about five days apart, beginning when the first eggs are hatching.

Recommended control chemicals are carbaryl, DDT, diazinon, or toxaphene at $1\frac{1}{2}$ to 2 pounds per acre, and EPN at $\frac{1}{4}$ pound per acre. Granular formulations are effective and easily applied. The granules tend to accumulate at the base of the leaf whorls where many borers enter the stalk. Sprays are about equally effective followed by dust formulations. Residues of these chemicals do not reach roasting ears or mature grains but do adhere to the remainder of the plant, especially sweet corn which generally receives a greater number of applications. Fodder from corn treated with DDT or toxaphene must not be fed to livestock; if treated with carbaryl, diazinon, or EPN the fodder may be fed to livestock zero, ten, and fourteen days respectively, after the last application was made. Good control often results, and no poisonous residues harmful to livestock remain on the fodder if the corn is sprayed with 6 pounds of 100% ryania powder, or 5 pounds of 5% rotenone powder in 100 gallons of water plus 5 ounces of wetting agent.

References: *U.S.D.A. Farmers' Bul.* 2190, 1962; *Dept. Bul.* 1476, 1927; *Conn. Agr. Exp. Sta. Bul.* 462, 1942; *Iowa Agr. Exp. Sta. Pamphlet* 164, 1950; 176, 1952; *Ohio Agr. Exp. Sta. Bul.* 429, 1928; 916, 1962; *J. Econ. Ent.*, 54:550–558, 1961; 56:804–808, 1963.

SOUTHWESTERN CORN BORER

Zeadiatraea grandiosella (Dyar), Family Pyralidae

A native of Mexico, the southwestern corn borer was found in Arizona, New Mexico, and Texas about 1913, and has now spread to Oklahoma, Colorado, Kansas, Nebraska, Arkansas, Louisiana, Mississippi, Alabama, Tennessee, Missouri, and Illinois.

Damage to corn results from the larvae feeding on the leaves, severing the terminal bud causing "deadheart," tunnelling in the stalks and ears, and girdling the stalks near the soil surface, causing stalk breakage (Fig. 132). Other hosts of lesser importance are forage- and grain-type sorghums.

Mature larvae, which are about $1\frac{1}{2}$ inches in length and are white with faint spots, pass the winter in the bases of corn stubble. Brown pupae appear in the larval tunnels in early June and adults emerge about a

Fig. 132. Typical stalk girdling by the southwestern corn borer. (Kansas Agr. Exp. Sta.)

week later. The adults are approximately $\frac{3}{4}$ inch long and of a soiled white-to-pale yellow color, the male being slightly smaller and somewhat darker. The wings are folded over the body when at rest (Fig. 133).

The eggs are laid during the evening, either singly or overlapping one another in chains or masses, on both upper and lower surfaces of leaves. Hatching larvae at first feed on the leaves and later enter the stalks. All larvae are dull white, with a regular pattern of conspicuous dark brown to black spots, except the overwintering forms. Pupation follows, with adult emergence by early August. These moths deposit eggs, and the larvae hatching therefrom become fully grown and form the overwintering stage. There are two or more generations per year.

Research shows the following will reduce borer damage: substitution of sorghum for corn, early planting, deep plowing of stubble, low cutting of stalks which removes hibernating larvae from the field, fall treatment to dislodge the stubble and expose hibernating larvae to atmospheric changes, resistant varieties, and natural enemies such as birds, insect parasites, and predators. *Trichogramma minutum* Riley and *Apanteles diatraeae* Muesebeck are perhaps the most important parasite species.

Chemicals that have given effective control are EPN and diazinon at

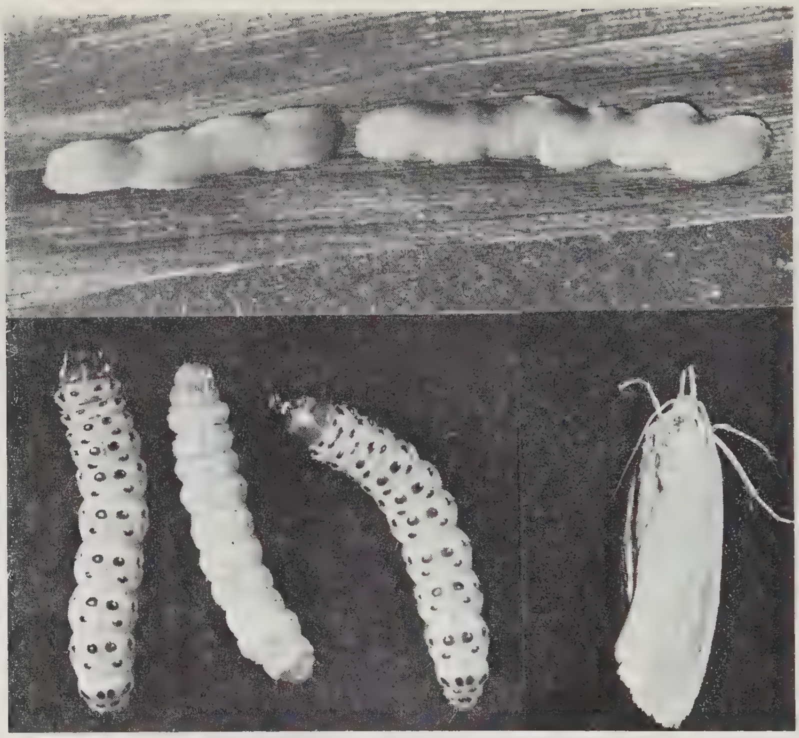


Fig. 133. The southwestern corn borer: (above) eggs; (below) spotted borers are the summer form, white borer is the overwintering form which girdles the stalk; (right) the adult moth. (Kansas Agr. Exp. Sta.)

rates of 1 and 1.5 pounds respectively, of actual chemical per acre. The first application should be made approximately nine days after hatching begins; this is repeated one week later. Follow the recommendations for your area.

References: *U.S.D.A. Tech. Bul.* 388, 1933; *Kansas Agr. Exp. Sta. Bul.* 339, 1950; *Ark. Agr. Exp. Sta. Bul.* 553, 1955; *J. Econ. Ent.*, 50:103, 1957; 54:16–21, 1961.

SOUTHERN CORNSTALK BORER

Diatraea crambidoides (Grote), Family Pyralidae

This destructive corn pest is found primarily in the region south of a line from the states of Virginia to Kansas. Other hosts are the sorghums and several related grasses.

Damage to corn closely resembles that done by the European corn borer. The tiny larvae feed on the leaves and midrib, and, as they in-

Fig. 134. The southern cornstalk borer, *Diatraea crambidoides* (Grote); adults and larvae. The nature of the injury is shown. (Leiby, N. C. Dept. Agr.)

crease in size, boring and tunnelling inside the stalks take place (Fig. 134). Much stalk breakage results from the feeding of the larger larvae. Because the larvae resemble closely those of the sugarcane borer, both are illustrated together (Fig. 138) for comparative purposes.

The inch-long, almost white, pale spotted larva passes the winter in the roots of corn stubble. Pupation takes place in the larval galleries in early spring, followed by moth emergence seven or more days later. The moths are straw-colored, and hold their wings tightly over the body when at rest, but when extended have an expanse of $1\frac{1}{4}$ inches. White oval eggs are deposited either singly or several overlapping one another, on both upper and lower leaf surfaces. The hatching larvae feed first on the leaves and later on the stalks; on becoming fully grown they pupate and then emerge as adults several days later. There may be as many as four generations per year in the warmer regions where this insect occurs.

Natural control results from several parasites and predators. The egg parasite *Trichogramma* has been reported as being important. Recommendations for applied control include destruction of the stalks immediately after harvest, fall and spring plowing of the stubble, late planting, and crop rotation.

References: *S.C. Bul.* 294, 1934; *N.C. Bul.* 274, 1920; *J. Econ. Ent.*, 46 : 176, 1953; *U.S.D.A. Leaflet* 363, 1954.

LESSER CORNSTALK BORER

Elasmopalpus lignosellus (Zeller), FAMILY PYRALIDAE

This insect has been sporadically numerous in the South for many years; its range extends from Maine to southern California, and in Mexico, Central and South America. Corn is a favorite host, but it also attacks sorghums, wheat, cowpeas, beans, peas, peanuts, turnips, and a variety of grasses.

The moth is brownish gray with a wing expanse of less than 1 inch. The fore wings of the female are darker than those of the male (Fig. 135). The larvae are slender caterpillars, about $\frac{3}{4}$ inch in length. The prevailing color is a light green, but there are faint stripes and more prominent transverse bands of brown.

The winter is passed in the soil as larvae or pupae. Adult moths emerge in the spring and lay their eggs on the host plants. The hatching larvae feed first on the leaves and then bore into the stalks, resulting in damage similar to that of the southern cornstalk borer. After feeding for about three weeks they leave their burrows and pupate in silken cocoons under debris at the soil surface. Adults emerge and begin laying eggs which become the next generation. There are two or more generations per year over most of the range they inhabit.

Control by sanitation measures, late fall plowing, and crop rotation are

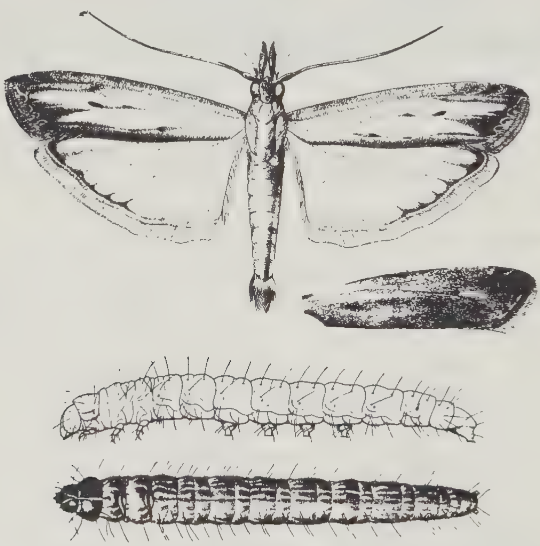


Fig. 135. The lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller); (above) male moth and fore wing of the female; (below) side and top view of a larva. (Luginbill and Ainslie, U.S.D.A.)

recommended and are usually adequate. Should the need arise, chemicals as suggested for the European corn borer might prove effective.

Reference: *U.S.D.A. Bul.* 539, 1917.

SORGHUM WEBWORM

Celama sorghiella (Riley), Family Noctuidae

This insect is frequently responsible for severe damage to grain sorghum crops. In 1882 it was first recorded in Alabama and has since been reported from most South Atlantic and Gulf Coast states. It is known to range northward to Nebraska, Illinois and Indiana. Injury is caused by the chewing larvae that attack and destroy the seed (Fig. 136). Other hosts besides sorghums are Sudan grass, Johnson grass, broom corn, and rye. Outbreaks are periodic and most likely to occur during seasons characterized by prolonged periods of rainy weather.

The adult is a moth with wings expanding a little more than ½ inch. It is nearly white in color with irregular dark markings along the anterior margins of the fore wings. Larvae are ½ inch long, greenish, with distinct darker stripes, and on each segment several bristle-bearing tubercles.

The winter is passed in the mature larval stage, on or in the food plant. Pupation follows in March, and normally the moths start emerging about April 1. Oviposition begins in a few days and continues throughout the growing season. The eggs are laid singly and cemented to the host plants. Hatching occurs in a few days, the larvae becoming fully grown in two

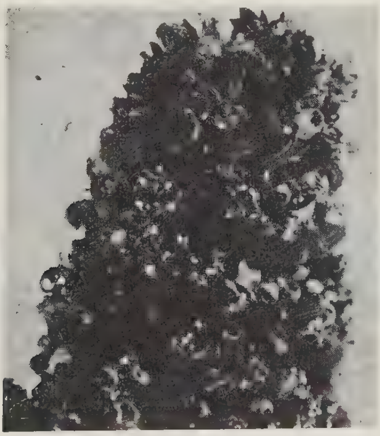


Fig. 136. The sorghum webworm. Larvae feeding on the head of the plant. (Reinhard, Texas Agr. Exp. Sta.)

weeks, after molting somewhere from four to seven times, but normally five. Pupation takes place within a cocoon spun by the larvae on the host, and in about a week adult moths of the next generation begin emerging. Six or more complete generations may develop each season.

Control measures practiced are primarily cultural or mechanical. Plowing under all crop residues in late fall to destroy the overwintering larvae, eliminating Johnson grass in the vicinity of sorghum fields during the winter, and planting early to mature the crop before injurious infestations develop are perhaps the most important. Although the insect is attacked by several parasites, these are not effective in preventing the development of injurious populations. The most effective natural control is dry weather accompanied by high temperatures.

If chemical control is necessary it may be accomplished with one of the following insecticides: carbaryl, Guthion, naled, parathion, or Phosdrin. Follow the directions on the packaged product.

References: *Texas Agr. Exp. Sta. Bul.* 559, 1938; *J. Econ. Ent.*, 56:483–484, 1963.

SORGHUM MIDGE

Contarinia sorghicola (Coquillett), Family Cecidomyiidae

This midge is considered the most important insect attacking grain sorghums. Its hosts include forty-eight varieties of grain and sweet sorghums, corn, Johnson grass, Sudan grass, and allied plants. Injury results from the feeding by the larva on the developing seeds. The midge ranges from Virginia to Nebraska south through the Gulf states, Arizona, New Mexico, and California.

Fig. 137. The sorghum midge, *Contarinia sorghicola* (Coq.). Adult female and larva in its cocoon. (Gable, Baker, and Woodruff, U.S.D.A.)

Larvae hibernate within cocoons in the spikelets of their host plants. In the spring these change to pupae and emerge as adults, which are tiny fragile flies (Fig. 137), similar to the adults of hessian fly and wheat midge. If conditions are not favorable some larvae remain dormant until the following year. Emergence continues for several weeks with the result that subsequent generations are produced about every fifteen days. These overlap to such an extent that the effect is a continuous production of all life stages throughout the summer. In the fall, a large number of larvae form cocoons in which they pass the winter.

Control measures suggested are plowing under crop remnants containing hibernating larvae; planting only seed of uniformly blooming strains; eliminating Johnson grass where possible; removing from the field "out-of-season" blooming heads; cleaning up fields after harvest; avoiding planting near earlier sorghums, Johnson grass, or other hosts; preparing a good seed bed and cultivating the field to produce as uniform a crop as possible; avoiding cutting hay while sorghum is blooming to prevent migration of egg-laying adults to the sorghum; applying carbaryl at $1\frac{1}{2}$ pounds, diazinon at 1 pound, or DDT at $1\frac{1}{4}$ pounds per acre when 90% of the heads have emerged. Other chemicals that have controlled this pest satisfactorily in experimental plantings are ciodrin, dimethoate, methyl parathion, and toxaphene.

References: *U.S.D.A. Tech. Bul.* 778, 1941; *Farmers' Bul.* 1566, 1959; *J. Econ. Ent.*, 56:454–459, 1963; *Proc. N.C. Branch Ent. Soc. Amer.*, 18:86, 1963.

SUGARCANE BORER

Diatraea saccharalis **(F.), FAMILY PYRALIDAE**

This insect is said to be native to the West Indies, Central and South America, but it has been known in this country since before 1856 and is now established in parts of Florida, Mississippi, Louisiana, and Texas. It is the principal pest of sugarcane and in the infested area causes loss amounting to a high percentage of the crop. Other hosts often seriously damaged are corn, sorghums, rice, and some wild grasses. This borer is closely related to the southern cornstalk borer and the southwestern corn borer.

Damage to all hosts is due to the larvae tunnelling inside the stalk, thus decreasing growth and weakening the plant until parts of it may die or break over, especially in high winds. Sugarcane damage is characterized by deadhearts of young plants, dead tops in older plants, broken stalks, loss in weight of sucrose, and injury to seed cane.

The sugarcane borers overwinter as larvae in tunnels of their host plant. As the temperature rises in the spring, they become active, extend their tunnels toward the plant surface until the covering of tissue remaining is very thin. Pupation follows, and the straw-colored moths (Fig. 138), with

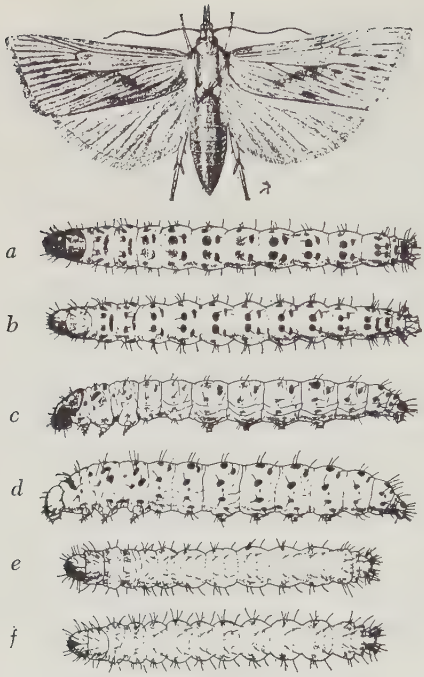


Fig. 138. (Above) the sugarcane borer adult; (below) dorsal and side views of larvae; *a* and *c*, the sugarcane borer, summer larvae; *e*, same, winter form; *b* and *d*, the southern cornstalk borer, summer form, and *f*, same, winter form. (U.S.D.A.)

a wing expanse of 1 inch, emerge from the stalks about a week later. After mating, the females deposit their eggs on the leaves of the plants. These overlapping eggs are in rows or clusters averaging about twenty-five or more per mass. Hatching takes place in four to nine days, and the tiny larvae at first feed on the leaves or in the whorl and then bore into the stalk. At the end of twenty to thirty days larval development is complete, pupation follows, and in about seven days the next generation of adults appears. There are four or five generations annually (Fig. 139). Fully grown larvae are about 1 inch long, pale yellow to white with brown spots, although in the winter these spots are almost absent and the color is a deeper yellow (Fig. 138).

Fewer borers pass the winter successfully if low temperatures and heavy rainfall prevail. Late freezes, heavy rains during the hatching period, and prolonged periods of dry weather also adversely affect the borers.

The egg parasite, *Trichogramma minutum* Riley, is of value in reducing

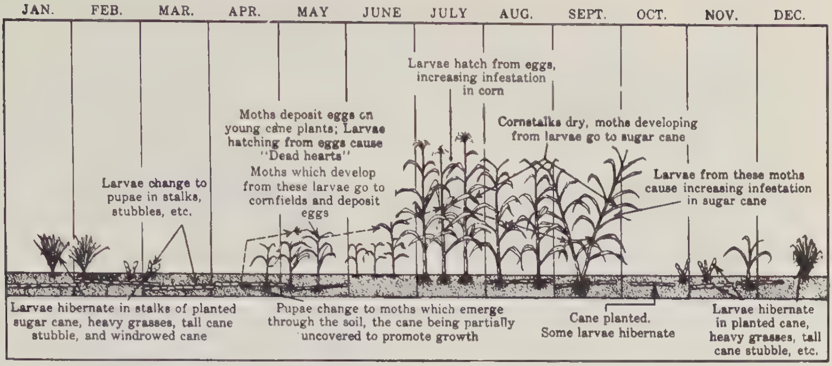


Fig. 139. Seasonal cycle of the sugarcane borer. (U.S.D.A.)

borer damage. A number of other native parasites have been found attacking the borers, but none of them has been in sufficient numbers to be of much value in control. Many species of birds are listed as predators of sugarcane borers and near relatives.

Applied control measures consist of more thorough clean-up of pieces of millable cane to eliminate overwintering quarters; burning or plowing under trash after harvest to destroy hibernating larvae; cutting low to decrease the number of borers overwintering in stubble; selecting seed cane as free from borers as possible; soaking seed cane in cold water for seventy-two hours kills a high percentage of the larvae; where agronomically practical plant resistant varieties such as C.P. 52–68, C.P. 34–79, C.P. 34–120, Cl. 38–32, and N. Co. 310.

If natural and cultural controls fail to provide adequate check of this pest an insecticide will be needed. Treatment is suggested to control only the second- and third-generation borers. Make the first application after the joints have started to form, and when at least 2% of the plants are infested with young larvae that have not bored into the stalks. Make four weekly applications of a dust containing 40% ryania at the rate of 12 to 15 pounds per acre. Cryolite, endosulfan, and guthion are other recommended insecticides.

References: *U.S.D.A. Tech. Bul.* 41, 1928; *Farmers' Bul.* 1884, 1941; *Cir.* 878, 1951; *Leaflet* 479, 1960; *J. Econ.*, 41:914–918, 1948; 52:821–824, 1959; 56:407–409, 1963; 57:350–353, 1964.

SUGARCANE BEETLE

Euetheola rugiceps (LeConte), Family Scarabaeidae

The sugarcane beetle (also called rough-headed cornstalk beetle) is found in most of the southern states. A serious pest of sugarcane wherever grown, except in southern Florida, it causes great loss of rice and corn in some

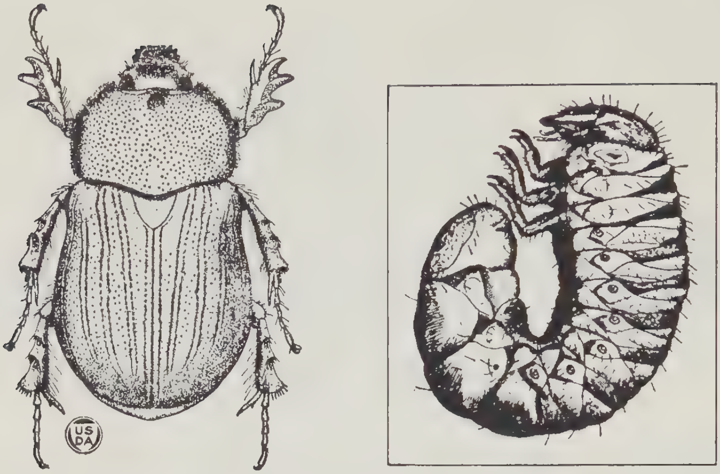


Fig. 140. The sugarcane beetle, *Euetheola rugiceps* (LeC.): (left) adult; (right) larva. (Phillips and Fox, U.S.D.A.)

localities, and also attacks cotton, strawberries, roses, and wild grasses. The adult beetles injure the host plants by chewing on the young shoots and leaves at ground level or slightly below. In rice fields this damage occurs before the fields are submerged.

Adult sugarcane beetles commonly overwinter in the soil of well-drained sod land. They become active during the first warm days of February and March, with feeding and ovipositing continuing through June. Most eggs are deposited in sod land near cultivated fields. The larvae (Fig. 140) are white, fleshy grubs with curved bodies, about $1\frac{1}{4}$ inches long when fully grown. They feed on the roots of grasses. Under laboratory conditions the average incubation period for eggs is fourteen days, for larval development eighty-five days, and for the pupal period nine days. New adults appear in August and September and feed for a short time before hibernation. There is only one generation per year.

Many natural enemies such as birds, toads, frogs, skunks, and a few insect predators and parasites reduce the population slightly but cannot be depended upon for control. Eliminating sod land breeding areas, especially near rice or sugarcane plantings; submerging rice fields; and planting sugarcane early in August, which gives a better stand and consequently less noticeable beetle damage, are all recommended control measures. Chemical control measures consist of soil treatment with aldrin or heptachlor.

References: *U.S.D.A. Cir.* 632, 1942; 878, 1951; *Leaflet* 520, 1963; *J. Econ. Ent.*, 51:631–633, 1958.

GRAY SUGARCANE MEALYBUG

Dysmicoccus boninsis **(Kuwana), FAMILY PSEUDOCOCCIDAE**

This mealybug is found throughout southern Florida and Louisiana, and on some farms in Georgia, Alabama, and Texas. Damage is caused by the nymphs and adults removing the sap from the cane plant, most often between the sheath and the stalk. Their presence also makes syrup manufacture more troublesome and generally lowers the quality of the product.

The female mealybug, which is more commonly seen than the male, is a soft-bodied, grayish insect about $\frac{1}{8}$ inch long when fully grown, and of a flattened oval shape, with small protruding processes near the margin of the body (Fig. 141). Its eggs are deposited within a white, cottony substance. Hatching nymphs migrate over the plant, feeding on the sap, with continuous generations occurring throughout the year. The eyes of fall-planted seed cane may be killed by the mealybugs, thus reducing the stand.

Suggested control measures are: planting uninfested seed cane in new fields some distance from those known to be infested; destroying all scraps of cane left on the fields and around the mills after grinding; when harvesting, cutting close to the ground so that less cane remains on which winter feeding may take place; avoiding contamination of new areas by thoroughly cleaning out trucks and wagons employed in hauling infested cane to the mills. Seed cane may be freed from infestation by soaking in hot water at 122°–126° F. for thirty minutes, or soaking in water at ordinary temperature for seven days. Ants are attracted to the honeydew secretions of the mealybugs, and perhaps elimination of the ants with

Fig. 141. The gray sugarcane mealybug. (U.S.D.A.)

chlordane will do much toward controlling the pest. If chemical control is needed apply phosphate type insecticides.

Reference: *U.S.D.A. Cir.* 878, 1951.

Sugarcane Weevil,* *Anacentrinus subnudus* Buchanan, feeds on corn, sorghums, and sugarcane. Most damage has been observed in Louisiana. The weevil is dark brown, about $\frac{3}{8}$ inch long and $\frac{1}{8}$ inch wide. The larva is a white legless grub with an amber-colored head; the pupae is white at first, assuming a brown tint before adult emergence. All stages of the weevil are found in sugarcane fields at almost any time of the year, but adults are more numerous in August and September and the larvae during the winter months. The larvae tunnel below and slightly above the surface of the ground in seed cane, the young plants and stubs, killing the cane eyes and providing easy entry for disease organisms. Injury is greatest in light, well-drained soils. The only effective control measure known is to plant vigorous varieties that withstand weevil injury and are resistant to red rot. No stage of the weevil has survived the soaking of seed cane in water at 122° F. for thirty minutes.

* *U.S.D.A. Cir.* 878, 1951.

CHINCH BUGS

Blissus leucopterus (Say), FAMILY LYGAEIDAE

The chinch bug is widely distributed throughout the United States, southern Canada, Mexico, and Central America but causes the greatest damage in the regions drained by the Ohio, Missouri, and Mississippi Rivers (Fig. 142). It is mainly a pest of corn and sorghums but also injures small grains and other grass crops. Lawns and golf courses may be severely damaged in years of chinch bug abundance. Native to the United States, this insect apparently fed on the prairie grasses before large acreages of cultivated grass crops were planted by man.

The damage results when the piercing-sucking nymphs and adults become numerous and remove plant sap, thus causing retardation of growth and sometimes death of the plant.

The black and white adults are scarcely $\frac{1}{5}$ inch in length, typically true bug in shape, with whitish wings which are marked by a dark triangle on their outer margins. Both long- and short-winged forms are found, but the long-winged form prevails throughout the central states. The legs and base of the antennae are red. Young bugs are bright red but become darker as they near the adult stage (Fig. 143).

Adult bugs hibernate in any shelter available but are most often found in greater abundance in heavy grass sod along roadsides, fence rows, and pasture lands. They emerge from hibernation quarters with the coming of

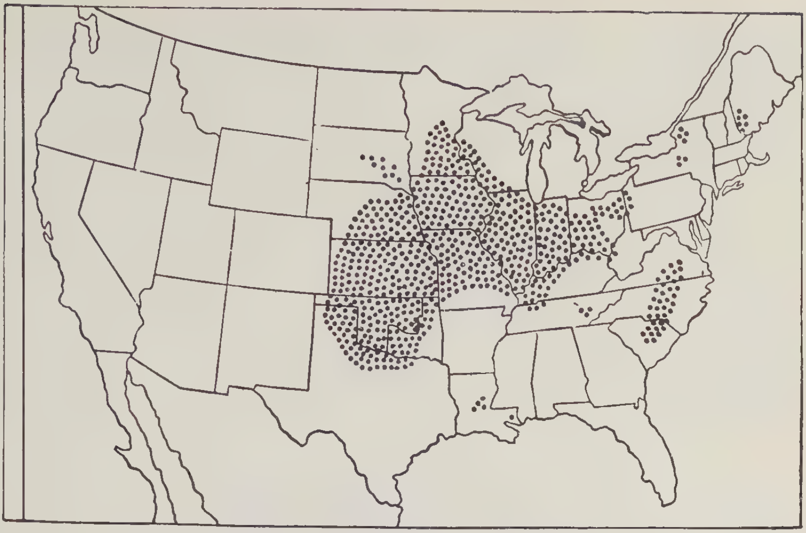


Fig. 142. Areas in the United States where the chinch bug occurs in most destructive numbers. (Webster, U.S.D.A.)

Fig. 143. Eggs, nymphs, and adult of the chinch bug, *Blissus leucopterus* (Say). (U.S.D.A.)

warm spring days and oviposit on small grains and grasses. Each female deposits several hundred yellow-white eggs, at the rate of fifteen to twenty per day, behind the lower leaf sheaths or in the soil around the plants. These hatch in one to three weeks into nymphs, which feed and pass through five instars before reaching the adult stage. As barley, rye, and wheat ripen the plants become less succulent, and the chinch bug nymphs

crawl to adjacent corn or sorghum fields where serious damage may result. It is during this migration period that barrier-trap control is effective. The new adults reach maturity about the middle to latter part of June and fly throughout corn and sorghum fields, laying their eggs, which hatch to form the next generation. By late summer or early fall second-generation adults appear which become the overwintering stage. In the extreme South, where activity begins earlier in the spring and continues later in the fall, a third generation usually develops. A partial third generation may occur as far north as Iowa.

The hairy chinch bug, *Blissus leucopterus hirtus* Montandon (Fig. 144), is sometimes considered only a variety of the other species. Primarily a turf pest, it is predominantly short-winged and is at times abundant in lawns in northeastern United States. Its life cycle is similar to that of *B.*

Fig. 144. Short- and long-winged forms of the chinch bug. (Britton, Conn. Agr. Exp. Sta.)

leucopterus. *B. insularis* Barber is the most troublesome form attacking grasses in lawns and golf courses in the South.

Weather is the chief factor governing the abundance of chinch bugs. They are most susceptible to mortality during the period of hatching. Frequent heavy driving rains during this period beat the young bugs into the soil, covers the eggs with mud which interferes with hatching, and prevents adults from ovipositing their full number of eggs. Extremely low temperature and sudden changes in temperature kill many adults during the winter and spring months. Hot, dry summer weather favors chinch bug development, and warm humid conditions favor the growth of the important natural enemy, white fungus disease, *Beauveria globulifera*

(Speg.). The spores of this fungus are present wherever the bugs are common, and they cause infection when the proper weather conditions prevail, making artificial dissemination unnecessary. A tiny wasp, *Eumicrosoma beneficum* Gahan (Fig. 145), is parasitic in chinch bug eggs and is considered of some importance in natural control. Birds which often feed

Fig. 145. Adult female of *Eumicrosoma beneficum* Gahan, a chinch bug egg parasite. Insert of male antenna. (Gahan, U.S.D.A.)

on chinch bugs are meadowlarks, brown thrashers, red-winged blackbirds, quails, and catbirds.

Cultural control measures consist of planting legumes that are immune to attack, or varieties of corn and sorghums that are decidedly resistant to attack. Growing soybeans or cowpeas in the field of corn, or a growth of clover in small grains produces a dense shade at the base of the plants which is unfavorable to the bugs. Damage may be reduced by avoiding adjacent plantings of small grains and corn.

Plowing under ruined fields of small grains or corn may be of some value in control if the soil is immediately disked and prepared into a dust mulch, thus preventing escape of the bugs. Burning over areas where the bugs are likely to hibernate may do more harm than good and is not recommended. Heavy watering of lawns reduces populations.

Barriers consisting of creosote-treated paper fences or ropes, a dirt ridge in combination with a creosote line, or a dusty furrow are no longer widely recommended or practiced for controlling chinch bugs. A more recent control recommendation is the employment of an insecticide barrier about 50 to 60 feet wide where fields of corn are adjacent to small grains. Half this treated area may be in the corn field and half in the small grain. The chemical should be applied beyond the end of the field for about 150 feet to prevent nymphs from migrating around the barrier. Treat the soil just before the nymphs begin crawling toward the corn; they are killed when they come in contact with the insecticide. Spray or dust formulations of dieldrin or toxaphene are often recommended for barrier strips. Usually one application is sufficient where the infestation is moderate. Where migration is very heavy, or the prevailing weather destroys the effect of

the chemical, additional applications may be needed. If large numbers of the bugs are found feeding on a few of the outer rows of corn, spraying or dusting them may be necessary. Other chemicals giving satisfactory control of chinch bugs, especially in lawns, are Dursban, DDT, carbaryl, diazinon, ethion, ronnel, trithion, and Zytron. Follow the recommendations prepared for your area by the extension entomologist.

References: *U.S.D.A. Farmers' Bul.* 1780, 1937; *Leaflet* 364, 1954; *Tech. Bul.* 585, 1937; *Cir.* 508, 1938; *Conn. Agr. Exp. Sta. Bul.* 677, 1966; *J. Econ. Ent.*, 48:240–245, 1955; *Ohio Agr. Exp. Sta. Bul.* 122, 1963.

SAP BEETLES

Order Coleoptera, Family Nitidulidae

The common name of this family of beetles is based on the habits of the species that are attracted to the wounds of trees where they feed on sap. At times some species become very serious pests of sweet corn grown for processing or for the roasting ear market. They enter the tip of the ear and feed on the developing kernels, particularly in ears already infested with corn earworm or damaged by birds. Adults are attracted to the more mature ears in a field, but under heavy infestation they will oviposit in any available, regardless of maturity. Some species also feed in ripened fruits and vegetables.

The primary pest species attacking sweet corn is the dusky sap beetle, *Carpophilus lugubris* Murray. Others are *C. antiquus* Melsheimer, *C. brachypterus* (Say), *C. corticinus* Erichson, *C. freemani* Dobson, *C. hemipterus* (L.), *Cryptarcha ampla* Erichson, and *Glischrochilus quadrisignatus* (Say).

The dusky sap beetle is dull black and about $\frac{3}{16}$ inch long with short elytra and capitate antennae (Fig. 146). Winter is passed as adults in protected places above ground, and as adults and pupae in the soil. Activity begins with warm spring weather, and early feeding is on sap from wounds on trees or on decomposing plant material. Adults are noticed in corn fields about the time tassels appear. Mating and egg-laying begin; the tiny white eggs are deposited in earworm frass, wet accumulations of pollen in leaf axils, corn silks, and in smut galls. Hatching occurs in two and one-half days at 75° F., and the white larvae pass through three instars in a period of fourteen days, then drop to the soil where pupal cells are formed a few inches below the surface. After a period of approximately fourteen more days new adults emerge and the cycle is repeated. The total developmental period is about thirty days and three to four generations occur annually in the latitude of Illinois. Some adult females lay over 300 eggs and live for 147 days.

Delayed planting averts damage in some regions. Damage is less where varieties with long tight husks are grown and where earworm is controlled

by insecticides. Recommended chemicals are carbaryl, diazinon, malathion, and DDT.

Glischrochilus quadrisignatus is known by several common names but picnic beetle seems appropriate when it becomes a nuisance in picnic areas of homes and parks. Abundance is attributed to breeding in melon

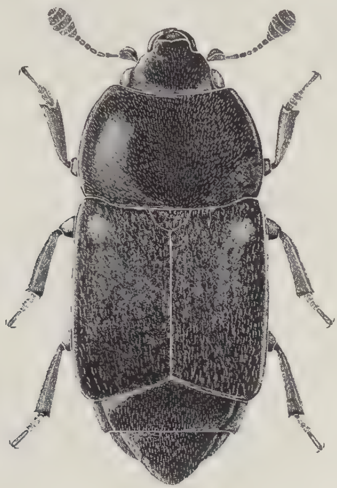


Fig. 146. The dusky sap beetle, *Carpophilus lugubris* Murray. (Drawing by C. A. Triplehorn, courtesy of W. A. Connell, Univ. of Delaware.)

rinds, tomatoes, sweet corn, and other fruits and vegetables discarded in picnic areas and at roadside fruit and vegetable markets.

Adults are nearly $\frac{1}{4}$ inch in length, black with four orange red spots on the elytra. Overwintering beetles become active by May and begin to oviposit. New adults reach abundance in July and September; they feed on damaged fruits, vegetables, and field crops until cold weather. Two generations develop each year.

Disposing of breeding materials contributes to lower populations of the picnic beetle. Control chemicals are aldrin, carbaryl, chlordane, diazinon, malathion, and DDVP baits.

References: *J. Econ. Ent.*, 49:539–542, 1956; 52:640–642, 1959; 53:174–175, 1960; 55:671–674, 922–925, 1962; *Del. Agr. Exp. Sta. Bul.* 318, 1956; *Proc. N. C. Branch Ent. Soc. Amer.* 18:38–43, 1963.

CEREAL LEAF BEETLE

Oulema melanopa (L.), Family Chrysomelidae

This pest, distributed widely in Europe, also occurs in Iran, Turkey, Morocco, and Tunisia. It was first found in the United States in July 1962, in Berrien County, Michigan. Subsequent surveys have shown it to be present in the bordering counties of Indiana and Ohio.

Both adults and larvae damage the young tender leaves of oats, wheat, barley, rye, corn, and grasses, particularly timothy and quack grass. The preferred host seems to be oats. The adults feed primarily on grain shoots and adjacent grasses, whereas the larvae eat out long narrow strips of tissue between the leaf veins. In some infested areas this damage has resulted in almost complete loss of the crop.

The adult beetle is slender and about $\frac{3}{16}$ inch in length; the elytra and head are metallic blue-black and the legs and prothorax are red; males are slightly smaller than the females. Overwintering beetles appear in the spring; following mating the females lay tiny cylindrical eggs that are rounded at the ends and yellow at first, darkening to almost black before hatching. Eggs are placed on the upper surfaces of the host plant leaves. The larva has a pale yellow body with brown-black head and legs, but it is usually covered by a globule of fecal matter that obscures its coloration except for the head and legs. Pupation occurs in earthen cells in the top 2 inches of soil, and adults begin emerging twenty to twenty-five days later. The entire life cycle may be completed in forty-six days. New beetles feed on grasses for a short period, then pass into summer diapause till autumn; then they hibernate under crop remnants until the following spring. Only one generation occurs per year.

Quarantines have been imposed in the infested areas to prevent spread of the insect in the movement of hay, straw, fodder, grains, sod and harvesting machinery. Fumigants have been useful in eliminating infestations in grains, forage, and straw.

Chalcid and ichneumonid parasites of the larval stage have reduced populations of this pest in its native country. The fungus, *Beauvaria bassiana,* has been found attacking the beetles.

Chemical control experiments indicate that carbaryl, lindane, guthion, or malathion will give satisfactory control.

Reference: *U.S.D.A.* PA-550, 1964.

CORN ROOTWORMS

Diabrotica spp., Family Chrysomelidae

The larvae of several species of beetles that feed on the roots of corn are called corn rootworms. Weakened root systems result and the plants

are easily blown down by strong winds. The adults are similar in size and form and eat the foliage and silks of corn. Some species attack other plants which they may damage more often than they do corn. Additional damage results to corn and cucumbers should the beetles carry and transmit the organisms of bacterial wilt to these plants. A brief discussion of some common rootworms follows.

Southern Corn Rootworm, *Diabrotica undecimpunctata howardi* Barber, is a widely distributed pest throughout southern Canada and the United States east of the Rocky Mountains, and it has a large host range. The adult is better known as the spotted cucumber beetle, since it often attacks cucumbers and is greenish yellow with 11 black spots (Fig. 147).

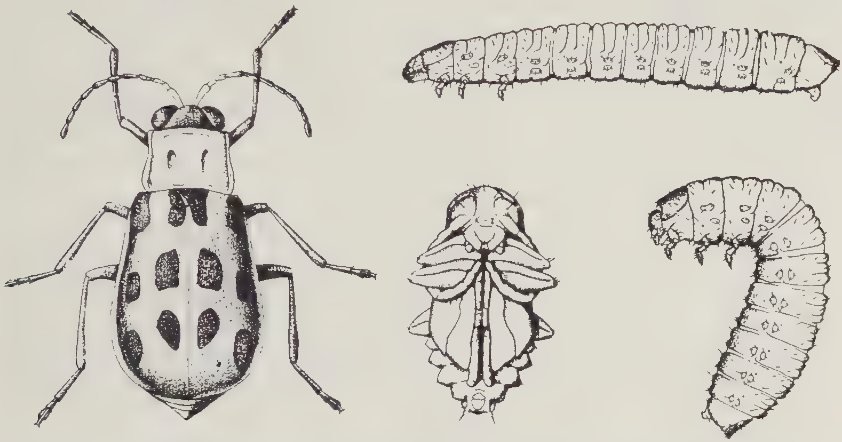


Fig. 147. The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber. Adult, larvae, and pupa. (Isely, Ark. Agr. Exp. Sta.)

Adults overwinter under crop remnants, become active in the spring, and lay their eggs in the soil next to the host plant. The tiny white larvae burrow in the roots, crowns, and stems and may even feed externally on the roots. Injury is especially serious to very young plants, and replanting is often necessary. There are two generations over most of its range, although in the northern limits there may be only one. This insect is a vector of cucumber mosaic virus and bacterial wilts of corn and cucumbers. It also causes serious damage to peanuts in the southern states.

Northern Corn Rootworm, *Diabrotica longicornis* (Say), is found in much of the range of the spotted species but does its most important damage in the corn belt. Adults are scarcely $\frac{1}{4}$ inch in length (Fig. 148) and are uniformly pale green or yellowish green. In the fall, eggs are laid in soil of corn fields, and these remain unhatched throughout the winter. In late

Fig. 148. Adult and larva of the northern corn rootworm, *Diabrotica longicornis* (Say). (U.S.D.A.)

spring the newly hatched larvae migrate through the soil and feed in or on corn roots should they be present. So far as is known they attack no other important food plants, and if corn roots are not available they die. Pupation takes place in the soil in the summer, and adults appear in late July and are present until frost. The adults often congregate and feed on the fresh corn silks, resulting in ears with few kernels. There is one generation per year. Since this insect attacks only corn and the eggs are laid in corn fields, rotation of crops is an effective means of control.

Western Corn Rootworm, *Diabrotica virgifera* LeC. (Fig. 149), is an important species primarily in Nebraska, Iowa, South Dakota, Minnesota, Colorado, and Kansas, but isolated infestations do occur rather widely in several adjacent or nearby states. The adults are strong flyers and voracious feeders of corn leaves and silks. Overwintering occurs as eggs in the soil, and one generation per year is typical.

Banded Cucumber Beetle, *Diabrotica balteata* LeC. (Fig. 150), has been observed feeding on corn but it is usually considered a general feeder with a southern range of distribution. Six or more generations occur per year in Gulf States.

Western Spotted Cucumber Beetle, *Diabrotica undecimpunctata* Mann., feeds, in its larval stage, on the roots of corn, grasses, and other plants. It is occasionally numerous enough in the western states to cause serious damage. The life cycle is similar to that of the southern corn rootworm.

Natural control results from ground and rove beetle predators; also from the tachina fly. *Celatoria diabroticae* (Shimer), and the nematode, *Howardula benigna* (Cobb), both of which are parasites of the adult stage. Protozoan diseases attack the northern corn rootworm.

Cultural control measures suggested for all species consist of rotation of crops, but effectiveness is limited to those which are specific to corn and overwinter in the egg stage; delaying the planting date is a means of avoiding attack from the larvae of the first generation of the southern

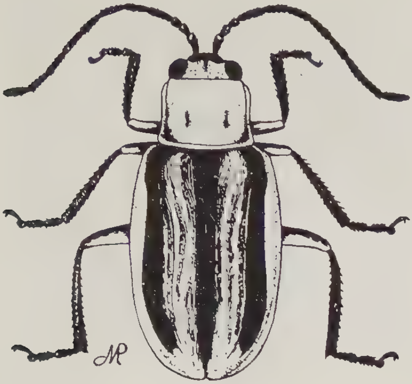


Fig. 149. Western corn rootworm, *Diabrotica virgifera* LeC. (Colo. Agr. Exp. Sta.)

Fig. 150. Injury to sweet corn by the banded cucumber beetle, *Diabrotica balteata* LeC. (U.S.D.A.)

corn rootworm; plowing in early spring or in the fall and frequent cultivation preceding planting reduce populations of most species.

Soil insecticides are effective for rootworm control when applied in any of the following ways: broadcast and disked in the soil, band treatment 6 inches wide on the row during planting, or mixed with the fertilizer. Emulsions, wettable powders, dusts, or the granular formulations are all recommended. Broadcast treatment requires higher rates of application than the band treatment. The following insecticides are suggested for rootworm control: aldrin, heptachlor, chlordane, or diazinon. Diazinon is especially recommended where resistance to chlorinated chemicals has developed.

These chemicals also offer some degree of control of wireworms and seed corn maggots.

References: *J. Econ. Ent.*, 55:904–906, 1962; 45:965–969, 1952; 46:217–224, 1953; 47:691–696, 1954; *W. Va. Agr. Exp. Sta. Cir.* 102, 1957; *Proc. N. C. Branch Ent. Soc. Amer.* 18:79–83, 92–95, 1963.

CORN FLEA BEETLES

Order Coleoptera, Family Chrysomelidae

Widely distributed, flea beetles may cause severe injury to corn, sorghums, broom corn, small grains, and other plants. The adults eat small holes in the leaves and the larvae destroy the roots. Some of these beetles

also serve as disseminators of bacteria causing wilt of corn or Stewart's disease (*Bacterium stewarti* Smith).

Important species are the corn flea beetle, *Chaetocnema pulicaria* Melsheimer; the toothed flea beetle, *C. denticulata* (Illiger); the sweet-potato flea beetle, *C. confinis* Crotch; the desert corn flea beetle, *C. ectypa* Horn; the pale-striped flea beetle, *Systena blanda* Melsheimer, and the western black flea beetle, *Phyllotreta pusilla* Horn. The corn flea beetle, *C. pulicaria*, is the major species responsible for harboring corn wilt bacteria over the winter and the secondary spreading of these organisms during the corn-growing season. Experiments have shown that *C. denticulata* ranks a close second in spreading bacteria causing Stewart's disease.

Most flea beetles overwinter as adults, emerge from hibernation in the spring, mate and lay their eggs on the leaves or on the ground near the base of the host plants. The tiny gray-white larvae with brown heads feed on the roots. Some species have a single generation per season, others having 2 or more. Adult beetles are less than $\frac{1}{8}$ inch in length, shiny black to dark gray in color, except the pale-striped flea beetle which is larger and has a broad, white stripe on each wing cover (Fig. 278). Flea beetle adults jump readily when disturbed.

Since the flea beetles also develop on many weeds, keeping fields and field borders as free of them as possible is of value in control. Frequent cultivation destroys or disrupts the activity of the larvae. Delaying the planting date and cultivation of wilt-resistant hybrid varieties of corn decrease the loss from Stewart's disease. Low winter temperatures will reduce overwintering populations. There is some correlation between the winter temperature index and incidence of corn wilt. This index is the sum of the average temperatures for December, January, and February in the area under consideration. An index of 90 or more is usually indicative of corn wilt outbreaks. The temperature data can be obtained from the local weather office.

Chemical control of adults has been considered satisfactory with DDT, carbaryl, or toxaphene applied as a dust or spray at the rate of 1 to 2 pounds per acre. Several applications about five days apart may be necessary. Treatment is not necessary every year but may be justified in years of flea beetle abundance after a mild winter.

References: *U.S.D.A. Tech. Bul.* 362, 1937; *J. Agr. Research*, 52:585–608, 1936; *Yearbook of Agriculture*, p. 587, 1952; *J. Econ. Ent.*, 55:1008–1009, 1962.

BILLBUGS

Sphenophorus spp., Family Curculionidae

Bill bugs, or snout beetles, are listed as pests of corn, small grains, other grasses, rushes, sedges, and, in the South, peanuts, rice, and sugarcane.

Fig. 151. The maize billbug, *Sphenophorus maidis* Chittenden. (Cartwright, S. C. Agr. Exp. Sta.)

Fig. 152. The clay-colored billbug, *Sphenophorus aequalis* Gyllenhal. (U.S.D.A.)

Injury is caused by the larvae eating the roots and crowns of plants and by the adults feeding on stems and foliage. The characteristic feeding punctures in corn and coarse grasses show up as a series of transverse holes of the same size and shape in the leaf. They are the result of a single puncture through the leaf in the bud stage before it has unfolded. Punctures in the stems are likely to cause more damage even though they are less noticeable.

Billbugs are more likely to be numerous in lowland areas, which are wet or subject to overflow from adjacent streams. Distribution of the various species is throughout the cultivated and grassland regions of the United States and Canada. The most common forms include the maize billbug, *Sphenophorus maidis* Chittenden; the clay-colored billbug, S. *aequalis* Gyll.; the bluegrass billbug, S. *parvulus* Gyll.; the curlew billbug, S. *callosus* Oliv.; the corn or timothy billbug, S. *zeae* Walsh; and the cattail billbug, S. *pertinax* Oliv.

The appearance of the various life stages is illustrated in Figs. 151, 152, and 153. The maize billbug is one of the largest forms and sometimes exceeds $\frac{1}{2}$ inch in length; other species range from $\frac{1}{4}$ to $\frac{1}{2}$ inch. The adults vary in color from light olive-yellow to brown and black. The prolongated head is quite characteristic of the adults and is the basis for the name "snout beetle." Larvae are short, thick-bodied, curved, legless grubs.

Billbugs have one generation per year. Overwintering adults are produced in late summer or fall and may be active and feed for a period, or may remain in the pupal cells until spring. They feed for a considerable

Fig. 153. Larvae and pupae of the maize billbug. (Cartwright, S. C. Agr. Exp. Sta.)

period in the spring, and may still be found when larvae are well grown or even after the next generation adults begin to appear. Eggs are laid in feeding punctures in the food plants, and the larvae feed in crowns and larger roots. In midsummer pupation takes place in the soil or in feeding cavities near the base of plants. The adult stage is reached soon afterward, thus completing the life cycle.

Natural enemies are of little value in control. Applied control measures have been very largely cultural or mechanical in scope. A crop rotation in which corn does not follow grassy sod is recommended where the clay-colored, bluegrass, or corn billbugs are a problem. Corn should not follow corn where the maize or curlew billbugs are causing damage. Good drainage, fall plowing, cultivation, destruction of rushes and sedges, all are recommended practices. Application of soil insecticides for these pests has not been studied thoroughly, but should an infestation develop any of those listed for wireworm control (p. 142) are suggested for trial.

References: *U.S.D.A. Farmers' Bul.* 1003, 1932; *S.C. Bul.* 257, 1929; 452, 1957; *J. Econ. Ent.*, 50:707–709, 1957.

RICE STINK BUG

Oebalus pugnax (F.), Family Pentatomidae

Practically all rice fields in Louisiana, Texas, and Arkansas suffer loss from the attack of rice stink bugs. This bug is also found in all rice-growing states east of the Mississippi River but is not found in California.

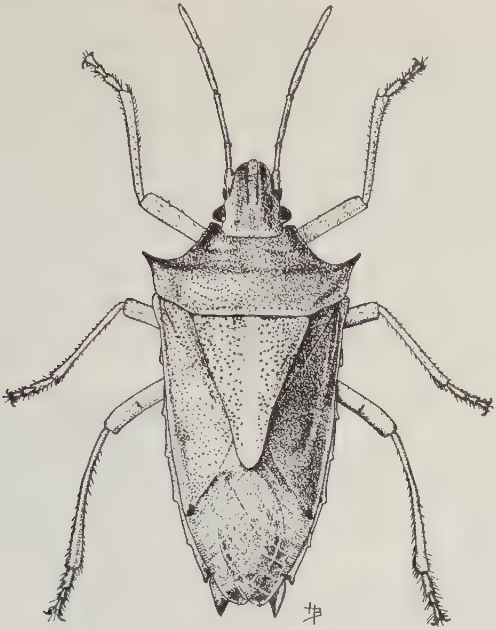


Fig. 154. The rice stink bug. (ARS–U.S.D.A.)

Besides rice, bullgrass (*Paspalum urvillei*) is the favorite wild host, but other grasses in or near rice fields are attacked.

Damage is caused by the piercing-sucking nymphs and adults feeding on the rice kernels in the milk and dough stages. Complete removal of the grain content in the milk stage results in an empty seed coat, and partial removal results in shrivelled kernels with spots varying from light yellow to black. Such injury is known to the rice trade as "pecky rice." This rice is graded down, lowering the market value, with the result that the average annual loss to the rice growers is approximately $500,000.

The adult is a straw-colored, shield-shaped bug (Fig. 154), which passes the winter in heavy grass near the ground surface. The bugs emerge from the winter quarters in April and early May, and begin depositing eggs on the blades of rice or grass. These light green, short, cylinder-shaped eggs are arranged in two rows on the upper surface, the number in a single cluster varying from ten to forty-seven. Their color develops a red tinge before hatching, which usually requires about five days. The nymphs molt five times in a period of fifteen to twenty-eight days and then become adults. There may be as many as four or five generations annually on grass, and two or three on rice.

Natural control results from their inability to survive the cold of win-

ter or periods of intense heat of summer; also included in natural control are the bird and spider predators, and the egg parasites, *Telenomus podisi* Ashmead and *Ooencyrtus anasae* Ashmead. Applied control consists of plowing or burning heavy grasses in which the bugs hibernate. It is probable that some of the chlorinated hydrocarbon insecticides will be effective in killing the early generations of the bugs.

Insecticides that have been effective in controlling this pest are carbaryl, malathion, phosphamidon, and toxaphene. Apply one week after the heads appear.

References: *U.S.D.A. Cir.* 632, 1957; *J. Econ. Ent.*, 55:648–651, 877–879, 1962; 56:197–200, 1963.

RICE STALK BORER

***Chilo plejadellus* Zincken, Family Pyralidae**

In habits this insect closely resembles the sugarcane borer, but the injury it causes is never as severe. Occasional injury from its feeding is noted in rice fields. It has also been found in corn.

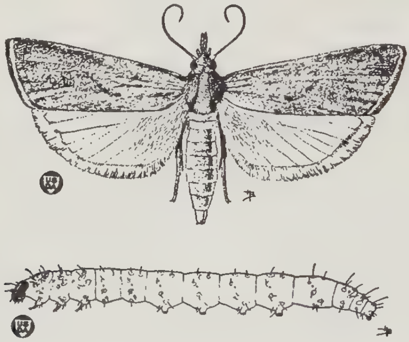


Fig. 155. The rice stalk borer, *Chilo plejadellus* Zincken. (Webb, U.S.D.A.)

The adult moth is similar to the sugarcane borer moth in size and shape (Fig. 155), and is not unlike it in coloration, being straw-colored with a golden tinge and marked with a sprinkling of minute black dots. Mature larvae are 1 inch in length, white and without stripes, the latter being characteristic of the sugarcane borer.

The winter is passed in the fully grown larval stage in the stubble. These transform to pupae in the spring, with adults emerging in June. At night the female moths lay their eggs, which hatch in seven days or more, with larval development complete in approximately one month, followed by pupation and adult emergence seven days later. There are two or three generations per year in rice fields.

Pasturing, plowing, or burning rice stubble in the winter greatly de-

creases the number of overwintering borers. A combination of dragging and submerging stubble fields in winter has resulted in 100% mortality of the hibernating larvae.

Reference: *U.S.D.A. Cir.* 632, 1957.

RICE WATER WEEVIL

***Lissorhoptrus oryzophilus* Kuschel, Family Curculionidae**

This native insect which feeds normally on semiaquatic grasses from New England to the Gulf states is a pest of the rice crop in most places where it is grown. Damage results from the larvae chewing off the roots of the young plants (Fig. 156) and the adults causing slit-like feeding

Fig. 156. Larvae of the rice water weevil, or root maggots, on roots of rice. (Webb, U.S.D.A.)

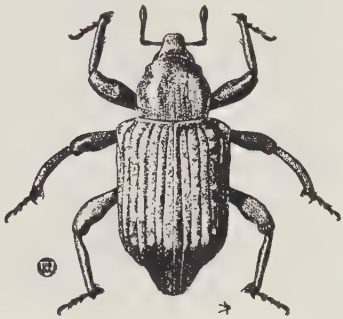


Fig. 157. The rice water weevil. (Webb, U.S.D.A.)

scars on the leaves which give the appearance of shredding. As the season advances the injury becomes less important.

The chewing-mouthpart adults are dark-colored, $\frac{1}{8}$ inch long, and shaped as illustrated (Fig. 157). They hibernate under grass or crop remnants during the winter and become active in the spring, the females depositing their white eggs in the roots soon after the rice fields are flooded. The slender, white, legless, aquatic larvae are nearly $\frac{1}{3}$ inch in length when fully grown. Larval development requires about five weeks, followed by pupation inside an oval cell of mud attached to the roots, with adult emergence occurring a week or more later. The total length of the life cycle is from thirty-five to fifty days, with two generations developing each year.

Experiments have shown that drainage undertaken for the purpose of

killing the larvae is not worthwhile. However, draining may be necessary in order to correct other unusual ills said to be caused by the larvae of the weevil. It is also possible that the larvae are associated with heavy root rot injury. Optimum control can be expected by treating the seeds with aldrin or heptachlor at the rate of 4 ounces of actual chemical per 100 pounds of seed.

References: *U.S.D.A. Cir.* 632, 1942; *J. Econ. Ent.*, 47:676–680, 1954; 54:710–712, 1961; 56:826–827, 893–894, 1963; *Ark. Agr. Exp. Sta. Bul.* 624, 1960; *Calif. Agr.* 13(8):10–11, 1959.

CORN ROOT APHID

Anuraphis maidiradicis (Forbes), Family Aphididae

When growth of corn is retarded, the leaves becoming yellow- or red-tinged coupled with a general lack of vigor, the grower may well suspect the presence of corn root aphids. These tiny blue-green, wingless aphids, which cluster on the roots of corn, cause injury by extracting the plant sap with their piercing-sucking mouthparts. The common host is corn, but other species of grasses, cotton plants, and many weeds, especially smartweed, are also attacked. This aphid can transmit maize dwarf mosaic virus.

The general appearance of the winged and wingless adults is shown in Fig. 158. The winged female has a black head, a dark brown thorax, and a pale green abdomen bearing three or four dark marginal spots and small dark specks over the surface. The antennae and legs are almost black.

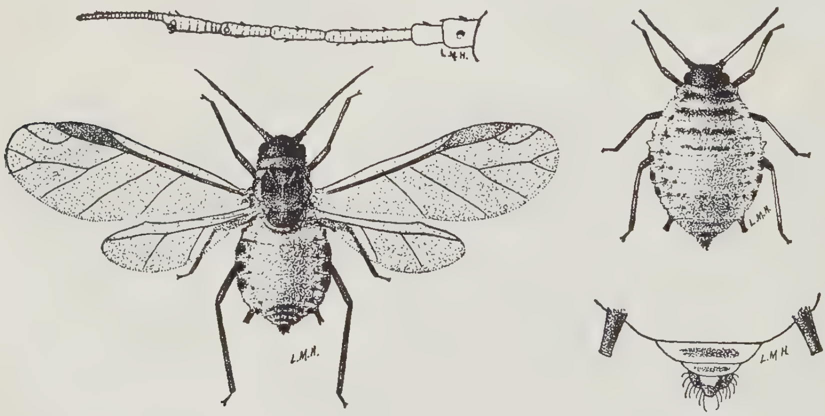


Fig. 158. The corn root aphid, *Anuraphis maidiradicis* (Forbes). Winged ovoviviparous female, wingless ovoviviparous female, and detail of abdomen of the latter. (Top left) antenna, greatly enlarged. (Hart.)

Glossy black, oval eggs overwinter in the soil nests of the cornfield ant, *Lasius alienus* (Föerster). These hatch in the spring into wingless nymphal females, which are carried by the ants to the roots of plants where they feed. The aphids become fully grown in two or three weeks and give birth to more of their kind. Since the female sex only is present, reproduction is by parthenogenesis. Winged females appear in the summer; they fly to other corn fields and start new infestations, if ants are present to care for the young. The period from birth to maturity is eight to sixteen days in the summer, with approximately twelve generations occurring during the season. In late September and in October wingless males and females are produced. These mate and the females lay eggs, which are carried by the ants to their nests in the soil. This cooperation on the part of the ants and aphids seems to be necessary for their survival. The ants feed on the excrement from the aphids, called "honeydew." It contains sugars from the plant sap on which the aphids feed. In turn, the ants care for the tiny, helpless aphids, place them on plant roots to feed, and protect the eggs during the winter period. A diagrammatic presentation of the life cycle is shown in Fig. 159.

Control of the corn root aphid can be achieved by rotation of crops, fall plowing to destroy the ant nests, spring plowing and cultivation to destroy ant nests and weeds on which the hatching nymphs feed.

Although extensive chemical control measures usually are not required, any of the following dust formulations will eliminate the ant population upon which the aphids are dependent: 5% chlordane, 2.5% aldrin, heptachlor, or dieldrin. These should be be applied at about twenty to thirty pounds per acre. If sprays are preferred use emulsifiable concentrates or wettable powders diluted with water to give an equivalent amount of the actual chemical per acre.

Reference: *U.S.D.A. Farmers' Bul.* 891, 1917.

GREENBUG

Schizaphis graminum (Rondani), Family Aphididae

The greenbug has also been called the spring grain aphid; it is doubtless the most destructive of the aphids that attack the small grains in this country. It has been reported from Canada to the Gulf states and from the Atlantic to the Pacific, but it is most likely to be destructive from Texas northward to Canada and eastward in the region north of the Ohio River. The insect has caused severe damage to barley, oats, and wheat in Texas, Oklahoma, Colorado, Kansas, and Nebraska. Its principal host plants are wheat and oats, but it can and does live on several kinds of grasses and other grain crops.

Development of the greenbug in numbers great enough to make it

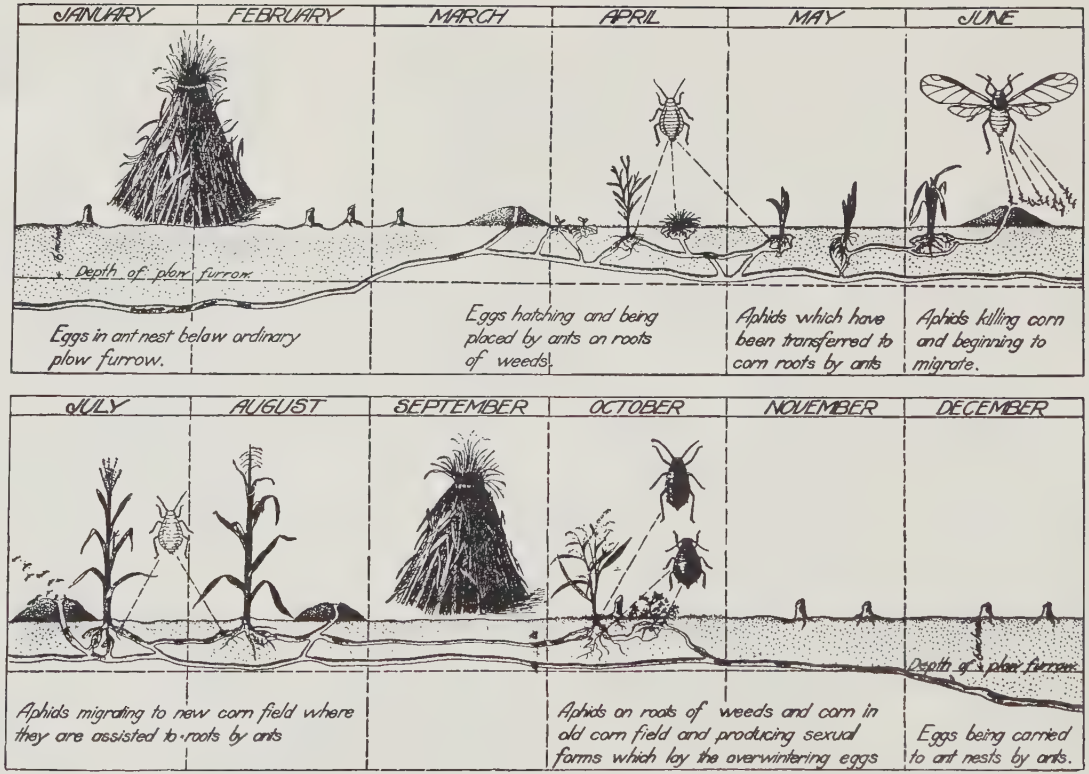


Fig. 159. Diagram showing life cycle of the corn root aphid and its relation to the cornfield ant. Note that during the winter the aphids are carried by ants below the frost line, where the plow cannot reach them. (J. J. Davis, U.S.D.A.)

the very serious pest that it occasionally becomes is the result of weather conditions which cannot be foreseen. It is capable of multiplying at temperatures as low as 40° F., whereas its insect parasites and predators, which usually keep it under control, can thrive only at temperatures above 65° F., so that during long periods of cool weather the greenbug increases to enormous numbers without much interference from its natural enemies. This relationship is apparently responsible for greenbug outbreaks in years when a cool spring follows a mild winter.

Epidemics of the greenbug often start in Texas and progress northward with the season. Their spread may continue until they reach the Dakotas and Canada, or they may be checked earlier.

In the South greenbugs remain active and produce living young throughout the year, resulting in more destruction in this area. Farther north adults may be found at all times, but they have what may be termed a hibernation period; still farther north shiny black eggs are laid on the food plant in the autumn, and the winter is passed in this condition. These hatch in the spring into female greenbugs. They are pale green and when fully grown have a dark green stripe down their back; the eyes, antennae, and tips of the appendages are black. The cornicles are moderately long and converge toward the tapering tip of the abdomen, rather than projecting outward as is usual with many aphids. The nymphs may develop into winged or wingless adults which give birth to young throughout the summer, resulting in numerous generations. In the North, with the approach of cold weather, winged males and females are produced, and after mating the females deposit the overwintering eggs (Figs. 160 and 161).

Natural control is due to parasites of which the braconid wasp, *Aphidius testaceipes* (Cresson), is by far the most important (Fig. 162). The usual predators, lady beetles, aphid lions, and syrphid fly larvae, contribute to keeping the aphids in check.

Fig. 160. The greenbug, *Schizaphis graminum* (Rondani); wingless oviparous female and winged ovoviviparous female. (Walton, U.S.D.A.)

Fig. 161. Greenbug eggs on leaf. (Walton, U.S.D.A.)

Fig. 162. *Aphidius* parasite in act of depositing eggs in the body of a grain aphid; much enlarged. (Webster, U.S.D.A.)

Cultural control consists of the destruction of volunteer grains, where feasible, by disking, plowing, or clean fallowing from harvest until seeding time. Chances of infestation are reduced sharply, so it is reported, when these measures are undertaken cooperatively by all the farmers in a given territory.

If chemical control becomes necessary apply one of the following insecticides: endosulfan, demeton, parathion, methyl parathion, malathion, lindane, or phosphamidon.

References: *U.S.D.A. Farmers' Bull.* 1217, 1921; *Leaflet* 309, 1951; *J. Econ. Ent.*, 44:954–957, 1951; 53:278–299; 473–474, 798–802, 1960; 54:606–607, 1171–1173, 1961.

OTHER GRAIN APHIDS

Order Homoptera, Family Aphididae

Besides the greenbug, other species of aphids attack grain crops and cause damage by removal of the plant sap with their piercing-sucking mouthparts, and by aiding in the dissemination of various virus disease-producing organisms. Their honeydew secretion often attracts ants and serves as a medium for sooty fungus.

Apple Grain Aphid, *Rhopalosiphum fitchii* (Sanderson), second to the greenbug in importance as an aphid grain pest, is also known as a minor pest of apple trees and related hosts. This aphid is a vector of yellow dwarf virus of barley. Mature wingless females (stem mothers), yellowish green with a distinct dark stripe down the back and several dark stripes across the body, develop from the overwintering eggs. These give birth to young, all

females and wingless. After two to four generations of these forms on apple trees, winged individuals develop which fly to grass and grain crops, and produce succeeding generations throughout the summer which are wingless and ovoviviparous. In the fall, the winged individuals are again produced in abundance. They fly to apple and related plants, and produce wingless females which are sexual forms. After mating, these wingless forms deposit the overwintering, shiny, black eggs. In the spring the eggs of the apple grain aphid hatch before those of other apple aphids, which is a way of determining the species present. Since all summer generations are females, reproduction is parthenogenetic.

Corn Leaf Aphid, *Rhopalosiphum maidis* (Fitch), is an occasional pest of corn foliage in late summer just at the time of tassel emergence. Severely injured tassels may turn white and fail to produce pollen. Infested leaves and ear shoots often become a mottled yellow or reddish yellow. Heaviest populations have been observed on hybrid varieties of field corn susceptible to the European corn borer. Other hosts are sorghums, barley, sugarcane, broom corn, and cultivated as well as wild grasses. This aphid is said to be world-wide in distribution.

The life cycle of these greenish blue aphids (Fig. 163) does not differ materially from those of other species. It is uncertain whether they winter in the North as eggs or become established annually by migrations from the South. As many as nine ovoviviparous generations may develop in Illinois, and up to fifty have been observed at Brownsville, Texas.

This aphid is a vector of the virus causing mosaic disease of sugarcane and its control where that crop is grown is therefore much more important than was formerly realized. It is also a vector of yellow dwarf virus of barley and maize dwarf mosaic virus of corn. The most dependable way to avoid corn leaf aphid injury is to plant resistant hybrid varieties of corn.

English Grain Aphid, *Macrosiphum avenae* (Fabricius), is a native of

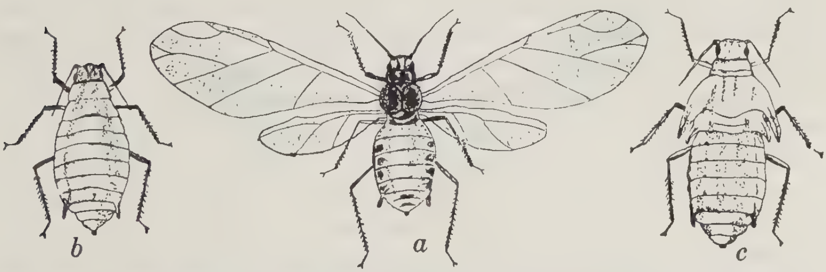


Fig. 163. The corn leaf aphid, *Rhopalosiphum maidis* (Fitch). *a*, winged, ovoviviparous female; *b*, wingless, ovoviviparous female, and *c*, last stage of nymph of winged form. (Forbes.)

Europe where it was first described. It is widely distributed throughout the United States and southern Canada, and attacks barley, oats, rye, wheat, corn, timothy, and other grasses.

Its feeding in early spring may kill young plants, and, after grain crops are heading, shriveled kernels may result. This aphid is rarely an important pest in this country. It is sometimes mistaken for the greenbug; however, the cornicles of this aphid are entirely black, whereas those of the greenbug are only tipped with black.

Another species of aphid found on grain crops and many wild grasses is *Rhopalosiphum padi* (L.). Its importance as a pest has not been accurately determined, but it is known to be a vector of the important corn virus disease known as maize dwarf mosaic.

Natural and applied control measures for all these species of aphids are the same as for the greenbug. Important parasites are the braconids *Aphidius testaceipes* (Cresson), *A. avenaphis* (Fitch), and *A. nigripes* Ashmead. In addition to the insecticides suggested for greenbug (p. 195), phorate, Di-Syston, and Telodrin are recommended should chemical control be required.

References: *Ohio Sta. Bul.* 464, 1930; *U.S.D.A. Tech. Bul.* 306, 1932; *J. Agr. Res.*, 7:463–480, 1916; *J. Econ. Ent.*, 53:197–200, 924–932, 1960; 57:22–23, 1964.

MINOR PESTS OF GRAINS AND GRASSES

Wheat Head Armyworm, *Faronta diffusa* (Walker), is occasionally a pest of developing heads of wheat and other small grains, but more often causes greater damage to the heads of timothy and related grasses. The dark caterpillars have rather broad, yellow and brown stripes along the sides of the body. When fully grown they reach a length of slightly more than 1 inch. After the pupae have been in the soil from September to April, the moths begin emerging, lay their eggs, and die. The larvae begin pupating in July, followed by adult emergence the latter part of the month and into August. The second-brood larval feeding period lasts from August until October, with fully developed larvae entering the soil and pupating during this time. Early harvesting of crops usually attacked, early fall plowing, and early fall pasturing are cultural control measures. Suggested chemical control measures are the same as those given for armyworms (p. 147) and cutworms (p. 153).

Grass Thrips, *Anaphothrips obscurus* (Müll.), or "oat bugs," sometimes extremely abundant and obscurely injurious, feed on the foliage, flowers, and developing heads of many grains and grasses with their rasping-sucking mouthparts. Slight injury is indicated by the appearance of scattered, tiny light gray spots, but with high populations the entire plant may become pale green or gray. Thrips commonly hibernate in plant remnants during

the winter and become active in late spring and summer, with overlapping generations occurring until autumn. In the summer they often migrate into buildings, their presence causing annoyance. Their numbers may be greatly reduced by plowing under crop residues during the hibernation period. Insecticides such as DDT, carbaryl, diazinon, methoxychlor, malathion, toxaphene, and lindane give effective control of thrips at commonly recommended dosages. However, usually nothing is done to control these insects on grass crops.

Range Crane Fly, *Tipula simplex* Doane, like other crane flies, is similar in adult form to a giant mosquito. The larval stage is a dark, leathery-appearing, footless worm which feeds on plant roots. This and related species are sometimes destructive in the range grasses of the Southwest; when abundant they may greatly reduce the pasturage over large areas. Eggs of the flies are laid in late winter and remain unhatched in the soil throughout the intervening dry season. Fall rains stimulate hatching, as well as root growth and feeding by the larvae which overwinter in the soil. Pupation occurs in February and adults emerge in March. Two days after adult emergence, the wingless females lay as many as one hundred eggs. They die soon afterward. Broadcasting poisoned bran baits, as suggested for grasshoppers, has been recommended. Treating infested soil in late fall or early spring with poisoned baits or sprays containing fenthion or guthion, has shown promise for controlling crane flies in Germany.

Reference: *Pflanzenschutz-Nachrichten-Bayer,* 17:1–24, 1964.

Brown Wheat Mite, *Petrobia latens* (Müller), is a tetranychid mite that sucks the sap from small grain crops, especially wheat. It occurs in most areas where wheat is grown in North America, but it does not cause serious damage every year. At times, chemical control measures may be necessary with parathion or demeton commonly recommended.

Winter Grain Mite, *Penthaleus major* (Dugès), is a eupodid mite that attacks small grains over a wide area of North America. In some years, and in some areas, damage becomes serious enough to require chemical control measures. Parathion and malathion are the commonly recommended chemicals.

Corn Planthopper, *Peregrinus maidis* (Ashmead), is a representative of the family Fulgoridae. Reports of its abundance in South Carolina, Texas, Florida, and nearby states have been made at various times. The nymphs and adults suck sap from the buds and leaves of late-planted and late-maturing corn. During the early part of the season, damage is often unnoticed because of the insect's small size. The appearance of the nymph and adult is indicated by Fig. 164. Suggested control measures are spraying or dusting with chemicals as given for the European corn borer.

Fig. 164. The corn planthopper, *Peregrinus maidis* (Ashmead). (Thomas, S. C. Agr. Exp. Sta.)

Say Stink Bug, *Chlorochroa sayi* Stål, is a shield-shaped (Fig. 217), piercing-sucking insect which causes injury to grains, grasses, cotton, sorghums, and some vegetable crops. A common wild host is Russian thistle. Damage to cotton is not evident until the bolls open, when the discolored fibers are revealed. Shriveled and shrunken kernels are the common type of injury to grain crops. Winter is spent as an adult, with eggs deposited in the spring and the nymphs passing through five instars. The period from egg to adult is approximately six weeks, and there are three or four generations per year depending on the locality. Control chemicals are carbaryl, DDT, Dylox, endosulfan, EPN, guthion, naled, parathion, methyl parathion, Strobane, and toxaphene.

References: *J. Econ. Ent.*, 57:60–62, 1964; *U.S.D.A. Agr. Handbook* 290, 1966.

Leafhoppers of several kinds suck the sap from grass plants and some are also vectors of viruses causing plant disease. Leafhopper vectors of corn stunt virus in the United States are *Dalbulus maidis* (DeL. & Wolcott) and *D. elimatus* (Ball). Predominant species are in the genus *Draecula-*

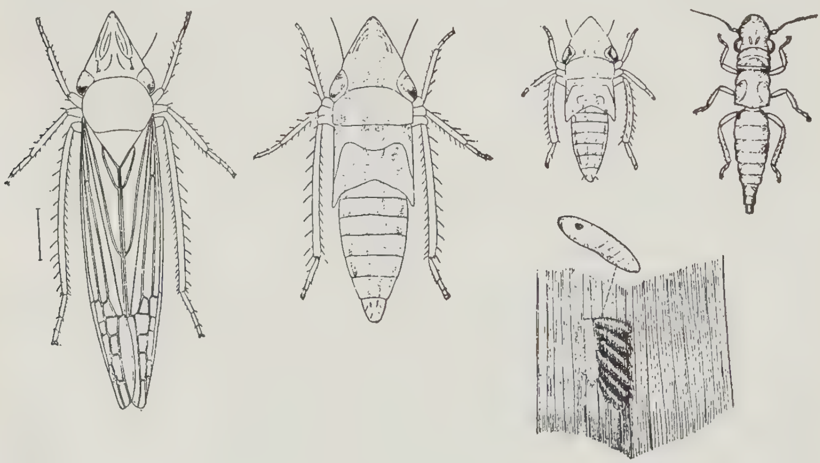


Fig. 165. The sharp-headed leafhopper, *Draeculacephala mollipes* (Say); adult, nymphs, and eggs. (U.S.D.A.)

cephala, with *antica, producta, portola, minerva,* and *mollipes* (Fig. 165) rather common. The aggregate damage caused by their feeding may be very great but this has been little studied. Life cycles of leafhoppers vary, some overwintering as eggs, others as adults. The number of generations also varies from one or more per year. Where feasible, satisfactory control can be obtained with 5% DDT or methoxychlor dust applied at the rate of 20 to 30 pounds per acre, preferably while the hoppers are in the nymphal stage.

HESSIAN FLY

Mayetiola destructor (Say), FAMILY CECIDOMYIIDAE

The hessian fly is one of the most destructive of all insects that attack the wheat plant. It was introduced from Europe during the Revolutionary War in straw bedding used by the Hessian soldiers, and was first found in the vicinity of a camp that they occupied on Long Island about 1779. Widely distributed in the wheat-growing regions of the world, its principal range in the United States is shown in Fig. 166.

In addition to wheat, the hessian fly occasionally damages barley and rye to a slight extent, and has been found breeding in emmer, spelt, and several wild grasses. The principal injury is caused by the larvae or maggots feeding between the leaf sheath and the stalk. By salivary secretion and intermittent sucking action they cause weakened stunted plants which often die in the winter. A central stalk frequently fails to develop. Damage in the spring is

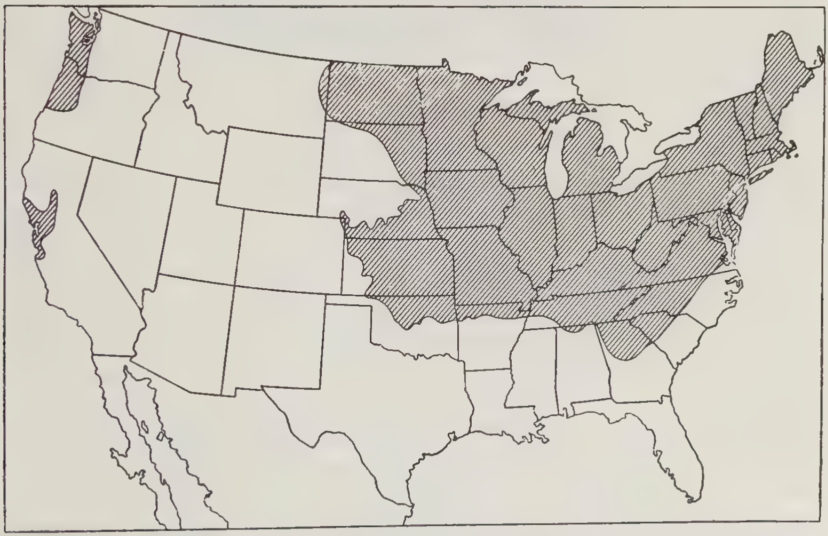


Fig. 166. The distribution of the hessian fly in the United States. (U.S.D.A.)

Fig. 167. The hessian fly, *Mayetiola destructor* (Say); adult male, (left) and female, (right). (U.S.D.A.)

similar, except that the weakened stalks often break over just before harvest and the heads are small and poorly filled with low-quality grains. Losses of grain in bushels per acre, resulting from counts of stems infested by the hessian fly in the spring, show a range of 0.04 bushels with a 1% infestation to 15.7 bushels when 100% infested.

There are normally two generations per year, but irregular generations may develop under the stimulus of unusual weather conditions, so that at times there may be three or even more. The usual designation is the spring or first generation and the fall or second generation.

The adult female is a minute, fragile fly, about 4 mm. in length, with the abdomen reddish-tinged; the male is slightly smaller, almost black in color with a pair of claspers at the tip of the abdomen (Fig. 167). Fall generation flies in late summer lay their tiny, elongated, yellowish red eggs end to end on the upper side of leaves of the host plants. These hatch in three to twelve days into legless maggots which are reddish at first, becoming white in the later instars. The tiny maggots migrate to the base of the leaf sheath where they feed between it and the stalk for a period of four to six weeks, after which they change to puparia. These are often referred to as the "flaxseed" stage because they resemble a true flaxseed in size, shape, and color. Overwintering puparia (Fig. 168) contain larvae until early spring when actual pupation occurs. This is followed by adult emergence of the spring generation a week or more later. Mating follows, and egg-laying begins soon afterward. Adult life is of short duration, lasting an average of two or three days. Maggots of the spring generation become fully grown and change to puparia in the stubble by late June, where they remain until late August or early September, after which fall generation adults again emerge. (See the diagram of the life cycle, Fig. 169). Most of the spring

Fig. 168. "Flaxseeds" or puparia of the hessian fly on young wheat; enlarged. (Pettit.)

generation larvae feed in the region of the first and second nodes but may occur higher (Fig. 170), depending upon the maturity of the plants at the time of infestation.

Many parasites play an important part in the natural control of the hessian fly. Those of special value are *Platygaster hiemalis* Forbes (Fig. 171), *P. zosine* Walker, and *Eupelmus allynii* (French). Other natural controls of value are climatic in nature, the most important being very hot, dry weather.

Applied control measures consist of sowing wheat on the "fly-free" dates (Fig. 172); destroying volunteer wheat on which the fall brood flies may oviposit, develop, and overwinter; plowing under infested wheat stubble soon after harvest, and disking the ground completely to prevent adult emergence; planting of resistant varieties of wheat, and selection of good

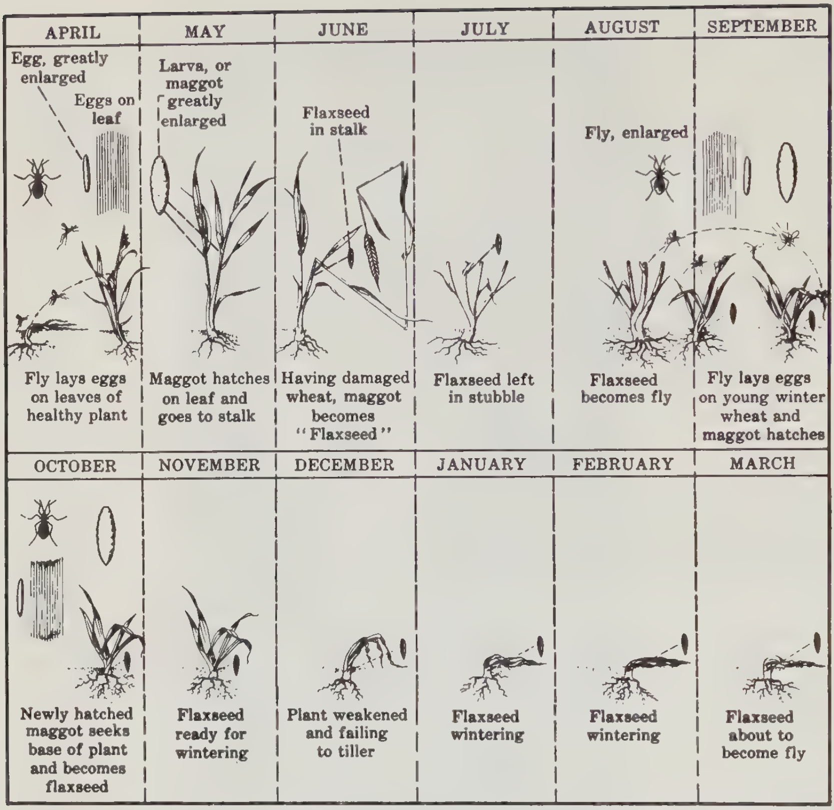


Fig. 169. Diagram representing the life cycle and activities of the hessian fly throughout the year. (U.S.D.A.)

seed, proper seed-bed preparation, and fertilizer. The safe sowing dates are based on the fact that the flies live only a few days, and the dates suggested have enough margin of safety so that all the adults will have emerged and died before the wheat comes through the ground. Community-wide cooperation is necessary for successful control. In California, adults emerge in March and April; therefore, early sowing is recommended, along with any cropping practice that favors production of vigorous growth. The mechanical destruction of volunteer wheat or infested stubble cannot be practiced where wheat is grown as a nurse crop for legumes or grasses. Varieties resistant to hessian fly attacks in the major wheat belt are the following: Pawnee, Ponca, Omaha, Warrier, Ottawa, Dual, Todd, Monon, Ace, Redcoat, Georgia 1123, Reed, and Knox 62. They are recommended especially for regions where it is impossible to get huge acreages of wheat

Fig. 170. Wheat stems showing appearance of the work of the spring generation of hessian fly larvae.

Fig. 171. *Platygaster hiemalis* Forbes, a parasite of the hessian fly. (Walton, U.S.D.A.)

planted at the proper time if sowing is delayed until the "fly-free" dates. In California, where the resistant varieties Big Club 43 and Poso 42 are grown, hessian fly is no longer a problem.

References: *Kansas Agr. Exp. Sta. Tech. Bul.* 11, 1923; *U.S.D.A. Farmers' Bul.* 1627, 1953; *Tech. Bul.* 81, 1928; *Tech. Bul.* 689, 1939; *Cir.* 663, 1943; *Leaflet* 533, 1965; *J. Econ. Ent.*, 49:182–184, 1956; 56:702–706, 1963.

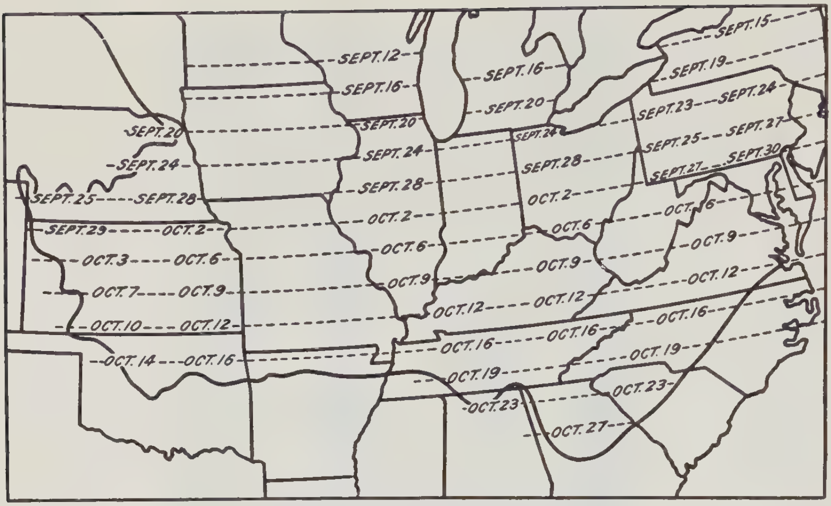


Fig. 172. Map showing the "fly-free sowing dates" for wheat to avoid damage from the hessian fly. These dates represent the average rather than definite dates for any one year. (U.S.D.A.)

WHEAT JOINTWORM

Harmolita tritici (Fitch), Family Eurytomidae

In the wheat-growing regions east of the Mississippi River, wheat jointworm at times ranks high as a pest. It has been found, but is of less importance, in Missouri, Utah, Iowa, Montana, Oklahoma, Kansas, Nebraska, North Dakota, South Dakota, Oregon, and California.

Heads of infested wheat plants have fewer and smaller kernels, and heavily infested fields show many "elbowed" straws. Occasional loss of heads occurs in harvesting.

Adult jointworms are about $\frac{1}{8}$ inch in length, black-bodied, four-winged,

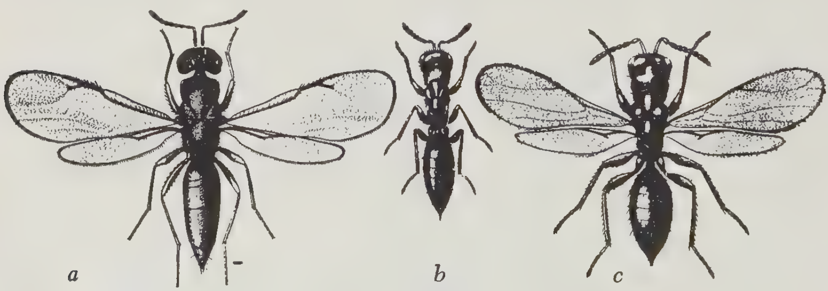


Fig. 173. *a*, the wheat jointworm; *b* and *c*, wingless and winged forms of the wheat straw-worm. (Knowlton, Utah Agr. Exp. Sta.)

and wasp-like (Fig. 173), with the joints of the legs yellow. They appear in wheat fields from April to July, according to the latitude, and lay their eggs in the stems near the joints. Several eggs are usually deposited in each place. The small legless grubs soon hatch, and their feeding causes the stem to develop the gall-like thickenings just above the second or third joint from the ground (Fig. 174). By harvest the galls or wartlike swellings become woody and brittle. Inside are found cells, each containing a single yellowish larva about $\frac{1}{8}$ inch long. From three or four to twenty or more of these larvae may occur in each gall, where they remain until winter when pupation takes place. In the spring the new adults emerge through small circular holes which they make by gnawing through the wall of their cells. These mate and fly to new wheat fields in the vicinity to lay eggs, thus completing the cycle. There is only one generation per year.

Infested wheat stubble plowed under in late summer or early fall to prevent escape of adults the following spring gives effective control. Objections to control by plowing, because it interferes with the growing of red clover and other hay or pasture crops, may be met by temporary substitution of such crops as soybeans and sweet clover for forage and green manure. In Oregon it is recommended that winter barley or winter oats be substituted for wheat as a nurse crop for red clover. When infestation is

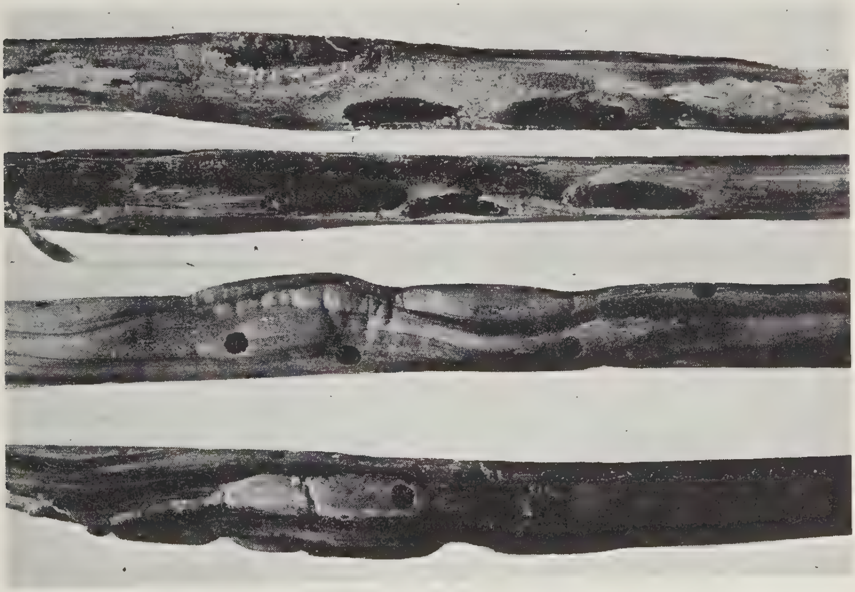


Fig. 174. Work of the wheat jointworm; burrows and pupal cells are shown inside the stems, above, and distorted stems with the exit holes appear below.

present, planting wheat far from the wheat fields of the previous year will reduce damage. Infested straw for bedding of livestock usually is thoroughly trampled and well rotted, thus killing most of the jointworms. Hauling this manure in the winter to the fields that are to be planted in corn and plowing it under before April also helps to eliminate jointworms. Burning straw and stubble will destroy the insects but is not recommended. Insecticidal control at present is not considered practical. Three species of parasitic wasps contribute to jointworm control.

References: *U.S.D.A. Tech. Bul.* 518, 1936; 784, 1941; *Farmers' Bul.* 1328, 1938; *Leaflet* 380, 1954; *Utah Bul.* 243, 1933; *J. Agr. Res.*, 21:405–426, 1921.

WHEAT STRAW-WORM

Harmolita grandis (Riley), Family Eurytomidae

This insect is most numerous and causes the greatest damage in the wheat-growing areas west of the Mississippi River, but it is found throughout most of the United States where wheat is grown, since this is the only host.

Winter is passed as larvae or pupae in the stubble or straw from the previous crop. In early spring the wingless, antlike, dark brown adults (Fig. 173) emerge and insert their eggs in the tissues of the host. On hatching, the tiny, yellow, legless larvae feed in the crown of the plant, causing stunting, and often destroy the central portion that later develops into the head. Pupation takes place within the stems in early May, and the winged adults of the second generation emerge a week or so later. These adults are larger and fly about depositing their eggs higher up on the plant, usually between the upper two nodes. Hatching takes place a few days later, and the larvae feed in the stems, weakening them and seriously interfering with head formation. By harvest time most of the larvae are fully grown; they remain in the stems and pupate there in the fall, passing the winter in this stage. There are two generations annually.

Natural enemies include some predators and parasites, which often attack jointworms as well. The most important parasite is the chalcid wasp, *Eupelmus allynii* (French). Another chalcid parasite, *Ditropinotus aureoviridis* Craw., has been recorded as important in Utah. The small elongate mite, *Pyemotes ventricosus* (Newport), feeds as a predator on the larvae in the stems and may be of considerable benefit in control. It is said that this mite is also predaceous on the parasites of the straw-worm.

If wheat is planted 60 to 80 yards from stubble or straw of the previous season, the wingless females of the first generation will not reach the new wheat. This forms the basis for the simplest of the control measures, which is crop rotation. Where wheat must follow wheat, growers are advised to

plow under the stubble and straw, and plant a late crop such as soybeans or cowpeas, disking this crop under before wheat-seeding time. Where only spring wheat is grown the destruction of volunteer wheat in the early spring will prevent infestation, since wheat planted at the regular time will not be up soon enough to be attacked by the adults from the overwintering pupae.

References: *U.S.D.A. Farmers' Bul.* 1323, 1923; *Dept. Bul.* 808, 1920; *Utah Bul.* 243, 1933.

OTHER JOINTWORM OR STRAW-WORM SPECIES

Order Hymenoptera, Family Eurytomidae

Wheat Sheath Jointworm, *Harmolita vaginicola* (Doane), is similar in appearance to *H. tritici.* However, the larvae do not develop in the tissue of the main stem but confine their attack to the leaf sheath. Although widely distributed, they are seldom abundant enough to cause serious damage, and no special control measures are needed.

Rye Jointworm, *Harmolita secale* (Fitch), and **Rye Straw-Worm,** *H. websteri* (Howard), are related species usually considered only of minor importance as pests of small grains. Both are widely distributed wherever rye is grown.

References: *J. Agr. Res.,* 34:483–488, 1927; *J. Econ. Ent.,* 25:1171–1172, 1932; *Utah Bul.* 243, 1933.

WHEAT MIDGE

Sitodiplosis mosellana (Géhin), Family Cecidomyiidae

Scattered around a wheat-threshing machine, and sometimes delivered through the spout with the grain, may be found small maggots, oval and flattened in shape and of a deep orange-red color. These maggots, often called "red weevil" by the growers, are the larvae of the wheat midge, a near relative of the hessian fly.

The very small and fragile mosquitolike adults (Fig. 175) appear in May and June, and lay their eggs inside the chaff scales protecting the developing kernel while it is in the milk or early dough stage. The larvae feed in the kernels, preventing their proper development. A heavy infestation materially reduces the yield. Outbreaks are infrequent and local; rye, oats, and barley also serve as hosts. About the time of wheat ripening, mature larvae begin dropping to the ground and changing into puparia. They remain in the ground as puparia until the following spring unless a second generation is produced, the evidence for which is meager. Farm practices designed to control the hessian fly should aid in reducing populations of wheat midge, particularly plowing under the old stubble when this fits the cropping

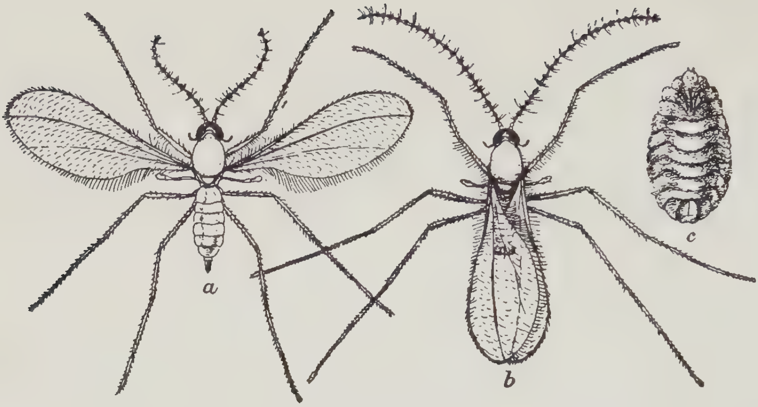


Fig. 175. The wheat midge, *Sitodiplosis mosellana* (Géhin): *a*, female fly; *b*, male fly; and *c*, larva. (Marlatt, U.S.D.A.)

program. If a high population develops, soil insecticides as recommended for wireworms might be of value in controlling this insect when it enters the soil before puparia formation.

Reference: *Purdue Agr. Exp. Sta. Cir.* 82, 1918.

WHEAT STEM SAWFLY

Cephus cinctus Norton, Family Cephidae

This native insect of wheat is found most abundantly in the northern portion of the Mississippi Valley and in adjoining provinces of Canada. Other common hosts are spring rye, barley, timothy, and native grasses.

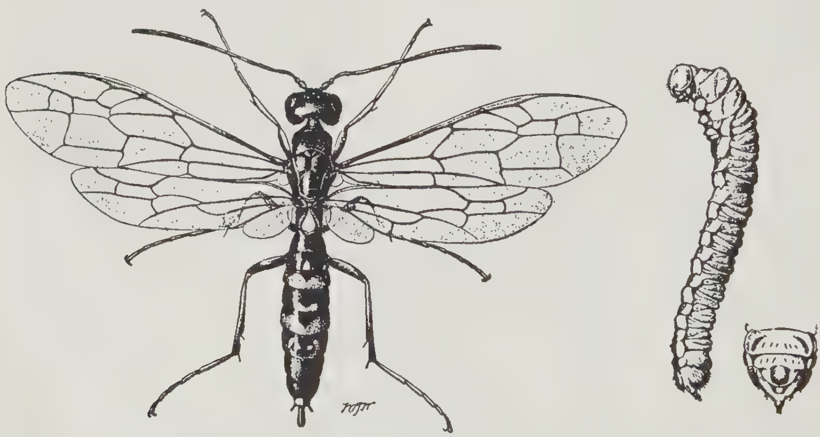


Fig. 176. The wheat stem sawfly, *Cephus cinctus* Norton; adult female and larva with detail of the last abdominal segment. (Walton, U.S.D.A.)

The adult insect (Fig. 176) is a small, slender-bodied sawfly of black and yellow color; the larva is a slender, yellowish, almost legless caterpillar-like worm that tunnels up and down inside the stems, weakening them enough to reduce the yield of grain or cause loss by stalk breakage. Fully grown larvae attain a length of ½ inch. By late July the larvae move to the base of the stems and gnaw a ring around each from the inside, weakening the straws which easily break off at ground level. Each infested stub is then plugged at the top and lined with silk-like material forming a chamber in which the larvae overwinter. Late in May of the following year pupation occurs, and adults begin emerging about June 10 and are present until about July 15. Egg-laying begins during this period with hatching taking place a few days after oviposition. This insect spends most of the year in the larval stage. Only one generation occurs annually.

Control may be secured by plowing under the stubble in the fall and working the soil to prevent escape of adults. Grasses that serve as alternate hosts should be destroyed where feasible. These include *Elymus condensatus*, *E. canadensis*, species of *Agropyron*, *Bromus inermis*, and timothy. Rotation of crops should also be of some value in checking the insect. Parasites that reduce the sawfly populations are *Bracon cephi* (Gahan), *B. lissogaster* Muesebeck, and *Eupelmus allynii* (French). Planting the resistant spring wheat varieties Rescue and Chinook has resulted in economical production in spite of this pest. Other resistant varieties are Golden Ball and Stewart.

References: *U.S.D.A. Tech. Bul.* 157, 1929; 1153, 1956; *Can. Dept. Agr. Pamphlet* 6, n.s., 1922; *Sci. Agr.*, 26:216–224, 231–247, 1946; *Can. Ent.*, 86:159–167, 1954; 89:272–275, 363–364, 1957; *Proc. N. C. Branch Ent. Soc. Amer.*, 15:100–101, 1960.

BLACK GRAIN STEM SAWFLY

Cephus tabidus (F.), Family Cephidae

First collected in this country before 1899, this insect has spread from its original location in New Jersey as far west as central Ohio and as far south as the Virginia-North Carolina line. Injury to wheat has been more serious in newly infested areas rather than in other sections of the distribution area. Infested wheat stems break off where they have been cut by the sawfly larvae, causing loss from shattering and difficulty in harvesting (Fig. 177).

Eggs are laid in the upper internodes of the stem about the time the wheat begins to head. Hatching follows in a few days, and the larva feeds on the inner lining of the stem, gradually working downward through the septa of the nodes until it has become fully grown and has reached the base of the plant at harvest time. It then forms a plug inside and, just below it, cuts a V-shaped incision completely around, with a thin outside fiber left intact, which holds the stem erect. Directly below this incision a second

Fig. 177. Wheat showing the work of the black grain stem sawfly, *Cephus tabidus* (F.). Note the blasted heads and the lodged straw. (Ohio Agr. Exp. Sta.)

plug is made, beneath which is a silk-lined cell where the larva spends the winter. Wind, or the weight of the head, causes the stems to break off. The remaining stub contains the inactive, overwintering larva which pupates in the spring, with adult emergence occurring in May. There is only one generation per year.

The European wheat stem sawfly, *Cephus pygmaeus* (L.), first recorded in New York in 1887, has spread southward through the eastern half of Pennsylvania to Maryland and Delaware. The damage and life cycle of this species and *C. tabidus* are similar, except that the adults of *C. pygmaeus* appear about a week earlier. Both species attack wheat and to a lesser extent rye. The larvae of *C. pygmaeus* do not completely cut the stem, and as a result an irregular, ragged edge is characteristic at the point where the stem is broken, whereas *C. tabidus* cuts the stem more completely, leaving a finely serrated edge at the point of breakage. The cut made by *C. cinctus* is similar to that of *C. tabidus.*

The major parasite of *C. tabidus* is the chalcid wasp, *Pleurotropis benefica* Gahan; the major parasite of *C. pygmaeus* is the braconid wasp, *Heterospilus cephi* Rohwer.

Recommended control measures are deep plowing of the stubble, with a clean turnover of the furrow slice to bury the overwintering larvae, where such procedure is feasible. To be successful this endeavor must be community-wide. Encouraging a strong stand by application of fertilizers and suitable cultural pratices also aids in reducing loss. Where infestation is

heavy much loss may be avoided by harvesting the wheat just before maturity.

Reference: *U.S.D.A. Cir.* 607, 1941.

OTHER WHEAT MAGGOTS

Wheat Stem Maggot, *Meromyza americana* Fitch, is widely distributed in the United States, Mexico, and Canada. It is native to North America, but its origin was probably in the southern portion of the continent. Food plants include all the small grains, timothy, and other species of grasses. Injury resulting from the maggots feeding in the stem above the upper node (Fig. 178) causes the heads of wheat and other hosts to ripen before the kernels are produced. These white heads in contrast to the green unripened grain make it easy to determine the presence of this insect. Wheat scab fungus also produces the same symptom but can be distinguished by the presence of the pinkish mold. Loss from damaged heads by stem maggot rarely exceeds 2 or 3%. In the winter wheat belt, damage by the fall generation is similar to that of the hessian fly.

Adult flies appear about June and deposit 25 to 30 eggs, singly, over a period of two or three weeks. Under favorable conditions hatching takes place in five days, the tiny white maggots complete their development in 18 to 22 days, and the pupal stage lasts 12 to 16 days. There are two or three generations annually in South Dakota, and a greater number are

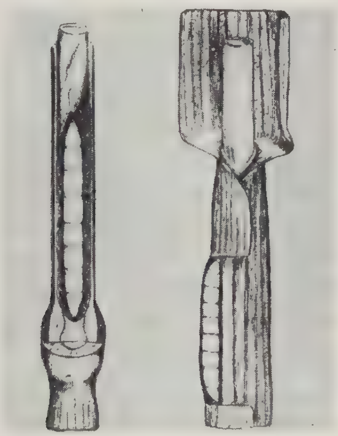


Fig. 178. The wheat stem maggot. Note positions in the stem and beneath the sheath. (Gilbertson, S. D. Agr. Exp. Sta.)

produced farther south. Winter is passed as larvae in winter wheat, rye, barley, or grasses.

Many natural enemies evidently are important in keeping this insect reduced in numbers. Two parasitic wasps have been found attacking the stem maggot larvae, parasitism sometimes being as high as 65%.

Rotation of crops, use of trap crops, destruction of volunteer grains and grasses, and late planting of fall grains should be considered in the applied control program.

Reference: *S.D. Agr. Exp. Sta. Bul.* 217, 1925.

Frit Fly, *Oscinella frit* (L.) (Fig. 179), is a widely distributed fly similar to the wheat stem maggot in appearance and in the injury that it causes. This species is of European origin. The American frit fly, *Oscinella soror*

Fig. 179. The frit fly, *Oscinella frit* (L.). (Aldrich, U.S.D.A.)

(Macquart), is very similar to the imported species. Methods of control suggested for the wheat stem maggot should reduce the damage caused by larvae of these flies. Silver topped panicles of bluegrass are caused by the frit flies, *O. neocoxendix* Sabrosky and *O. coxendix* (Fitch). Very few seeds are produced by such plants. At times frit fly larvae become damaging to turf in lawns and golf courses. For treating such areas apply DDT or other chemicals as given under wireworms (p. 142).

References: *Conn. Agr. Exp. Sta. Cir.* 212, 1960; *J. Econ. Ent.*, 55:865–867, 1962.

PLANT BUGS

Order Hemiptera, Family Miridae

Several species of plant bugs that attack grass and forage crops also cause serious damage to vegetables, flowers, nursery plantings, and orchard fruits. The injury results from the removal of plant sap by the piercing-

sucking mouthparts of the nymphs and adults. Legume and grass crops in bloom are often damaged to such an extent that very little seed is produced. Fruits such as apples, peaches, and strawberries are frequently misshapen.

Meadow Plant Bug, *Leptopterna dolabrata* (L.), feeds primarily on bluegrass, timothy, redtop, and orchard grass. The adults are scarcely ½ inch in length, green with fuscous markings, and two longitudinal black stripes over the pronotum and scutellum. Two forms of females

Fig. 180. The meadow plant bug, *Leptopterna dolabrata* (L.); (left) short-winged female; (right) long-winged female. (Jewett and Townshend, Ky. Agr. Exp. Sta.)

occur, one with short wings and the other with long wings (Fig. 180). Overwintering, yellow, curved eggs in the stems of grasses (Fig. 181) begin hatching as early as April 1, in the latitude of Lexington, Kentucky. The yellow-green nymphs with black markings transform to adults in May. Egg-laying takes place ten to fourteen days later, after which the adults soon die. There is only one generation per year.

Tarnished Plant Bug, *Lygus lineolaris* (P. de B.), feeds on a wide variety of plants. In its northern range the overwintering adults are found under

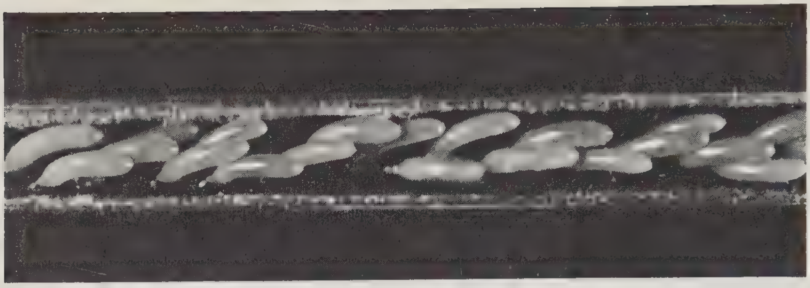


Fig. 181. Eggs of *Leptopterna dolabrata* (L.) in a stem of Kentucky bluegrass. (Jewett and Townshend, Ky. Agr. Exp. Sta.)

debris or in other protected places. These adults are scarcely $\frac{1}{4}$ inch in length, brown or yellow and sometimes green, with darker markings (Fig. 215). They become active in early spring and deposit their curved eggs in the stems, petioles, midribs, and blossoms of the host plants. Hatching takes place about a week or more later, and the green-to-yellow nymphs molt five times, reaching the adult stage in approximately thirty days. There are three to five generations or more annually, depending on the latitude. This species causes cat-facing of peaches and misshapen apples and strawberries.

Blue Grass Plant Bug, *Amblytylus nasutus* (Kirschbaum), is reported to be as numerous in some years as the meadow plant bug. It causes serious damage to Kentucky bluegrass seed production. The overwintering eggs are found only in stems of Kentucky bluegrass. In April these hatch into pale green nymphs, and thirty to thirty-five days later the green-yellow, winged adults appear, deposit their eggs, and soon die. In Kentucky, egg-laying begins about May 24, and all adults are dead by mid-June, there being only one generation per year. Twelve bugs per sweep of an insect net warrants chemical treatment.

Control measures for plant bugs are successful with any of the following chemicals: carbaryl, chlordane, DDT, diazinon, Dylox, malathion, methyl parathion, naled, parathion, Strobane, and toxaphene. Some of these materials are quite hazardous to use. Selection of the proper chemical and dosage should be made with the advice of your area extension entomologist. Burying the overwintering stages by plowing reduces plant bug populations.

References: *Ky. Agr. Exp. Sta. Bul.* 508, 1947; *J. Econ. Ent.*, 56:532–533, 555–559, 1963; 57:181, 1964.

10

Insects Injurious to Cotton

The growing of cotton is one of the major sources of income for the southern farmer. Because of this, it is essential to know the habits of the many insects that attack the crop, the damage they do, and their control. This chapter deals with major species of insects and mites attacking the cotton plant. However there are other insects sometimes destructive to cotton which are discussed in detail in Chapter 8. They are: grasshoppers, field crickets, wireworms, white grubs, fall armyworms, common stalk borers, cutworms, and armyworms.

The Agricultural Extension Service in each cotton-producing state issues an annual guide for controlling cotton pests. Obtain a copy of this guide for the insecticides and dosages recommended for your area.

BOLL WEEVIL

Anthonomus grandis Boheman, Family Curculionidae

Originally occurring in Mexico, this insect invaded Texas before 1892 and has since gradually spread until it occupies almost the whole of the cotton belt except California, New Mexico, and Arizona. The map (Fig. 182) shows the approximate yearly rate of spread. One of the most destructive insects ever known in America, the boll weevil has caused an estimated average loss in cotton fiber and cottonseed of more than $203 million annually since 1909. The loss exceeded $500 million annually in each of five years between 1915 and 1955.

Boll weevils pass the winter as adults in debris, crop remnants, or other protected places near cotton fields. They are brown, or gray brown-to-nearly black, snout beetles, about $\frac{1}{4}$ inch in length, although there is considerable variation in size (Fig. 183). The front legs are disproportionately large and prominent with two spurs near the end of the femora. Weevils emerging from hibernation feed on the foliage of cotton plants but do their greatest damage when the squares and bolls appear. They puncture the squares and bolls by boring into them with their chewing mouthparts, causing many to drop off. Each female may deposit over 175 eggs during her life span, usually placing a single egg in a feeding puncture of each

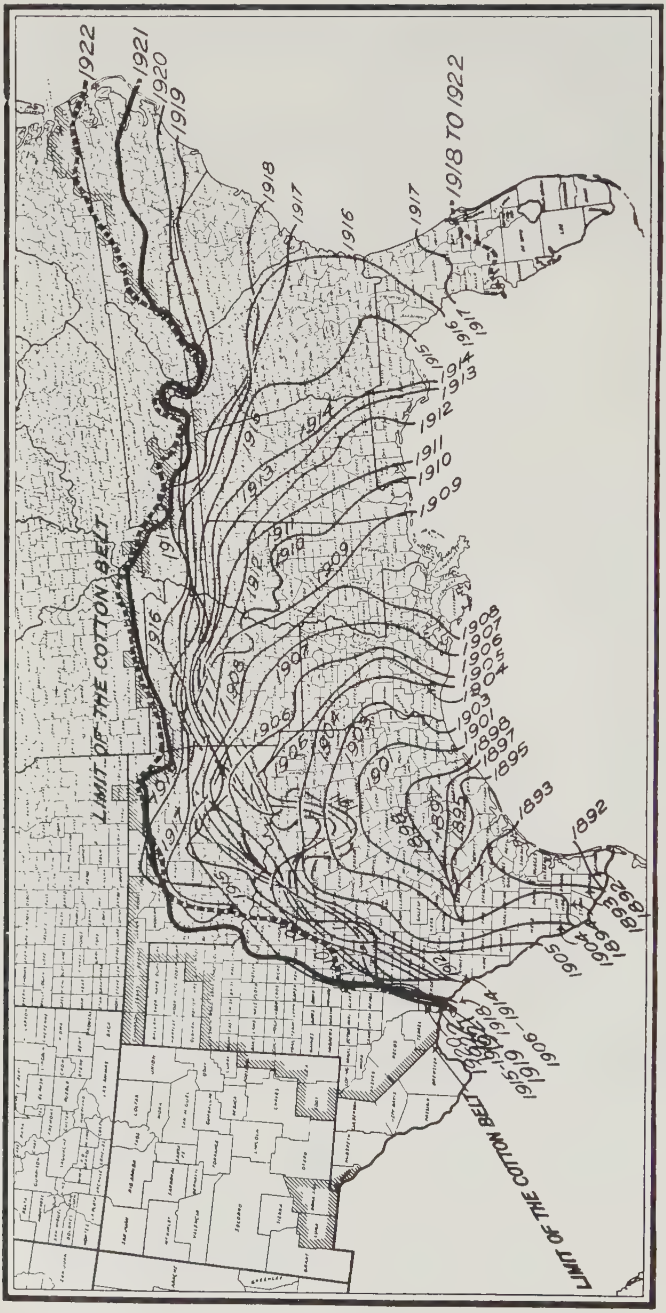


Fig. 182. Map showing spread of the cotton boll weevil in the United States from 1892 to 1922, inclusive. (U.S.D.A.)

Fig. 183. The boll weevil; natural size range indicated in the lower figure.

square or boll. After three to five days the eggs hatch into white, curved-bodied, legless larvae with brown heads and chewing mouthparts (Figs. 184, 185, and 186). These feed within the squares or bolls for seven to fourteen days and then transform into the pupal stage, which lasts about five days. Adults emerge and eat their way out; after feeding for about four days, egg-laying begins anew. The cycle from egg to adult requires about three weeks' time, and there may be seven or more complete generations annually.

Low winter temperatures and hot dry summers help control the boll weevils. Usually the weevils increase rapidly and severe damage results during rainy periods in the summer.

Many birds, insect predators, and parasites assist in reducing the boll weevil population but, up to the present time, control by such biological means is not considered to be of great value. About 80% of all parasites reared from boll weevil larvae have been *Bracon mellitor* Say (Fig. 187). Another parasite of importance is *Eurytoma tylodermatis* Ashmead (Fig. 79).

Cultural practices that help set bolls quickly will aid in reducing dam-

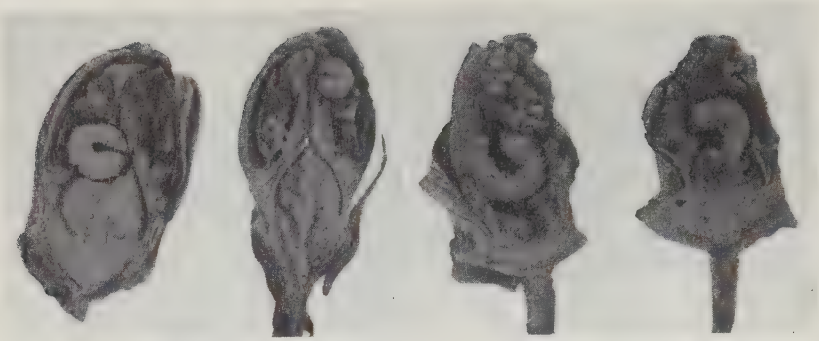


Fig. 184. Larvae of the boll weevil in opened cotton squares.

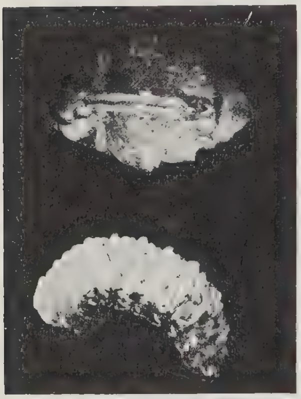


Fig. 185. Boll weevil larva and pupa.

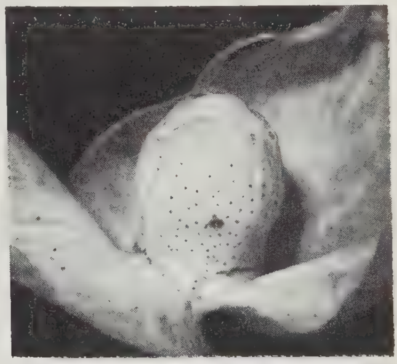


Fig. 186. Cotton square with bracts opened to show weevil damage on the bud, which shows a feeding puncture.

age. Those recommended are: planting early on good land, properly fertilized and well-prepared; choice of an early-maturing variety suited for the locality; plants spaced closely, cultivated frequently, picked early and clean; after picking, further fruiting should be prevented by chemical defoliants and desiccants, and by plowing, cutting, or grazing the cotton stalks early in the fall in order to check the development of a high population of overwintering weevils. Any practice which tends to reduce shelter for hibernating weevils also contributes to the control program.

Variations in the toxicity of insecticides approved for boll weevil control have been observed in local areas of the cotton belt, and the proper choice must be determined by their effectiveness in a given area. Start applications when 10% of the squares are punctured and repeat every

Fig. 187. *Bracon mellitor* Say, one of the most important parasites of boll weevil larvae. (Hunter and Hinds, U.S.D.A.)

four or five days until the infestation is brought under control. Weekly inspections thereafter should be made to determine when additional treatment is needed.

Insecticides that have satisfactorily controlled the weevil in one or more areas are indicated in the following table.

Insecticide	Type of Application	Pounds of Active Ingredient per Acre
Aldrin	Dust or spray	0.25– 0.75
BHC (gamma isomer)	Dust or spray	0.3 – 0.5
Bidrin	Dust or spray	0.5 – 1.0
Calcium arsenate	Dust	7.0 –10.0
Carbaryl	Dust	1.0 – 1.5
Chlordane	Dust or spray	1.0 – 1.5
Dieldrin	Dust or spray	0.15– 0.5
Endrin	Dust or spray	0.25– 0.5
Guthion	Dust or spray	0.25– 0.5
Heptachlor	Dust or spray	0.25– 0.75
Malathion	Dust or spray	1.0 – 2.0
Methyl parathion	Dust or spray	0.25– 0.75
Methyl trithion	Dust or spray	0.3 – 0.5
Strobane	Dust or spray	2.0 – 4.0
Toxaphene	Dust or spray	2.0 – 4.0

If resistance to the chlorinated hydrocarbon compounds is indicated, apply organo-phosphorus compounds, calcium arsenate, or carbaryl.

Because of other insect and mite pests on cotton the selection of the proper chemical and dosage should be made with the help of your local extension service representative.

References: *U.S.D.A. Farmers' Bul.* 1329, 1923; 2147, 1962; *Yearbook of Agriculture,* pp. 501–504, Plate I, 1952; *Ark. Bul.* 271, 1928; *Agr. Chemicals,* 8:34–35, 1953; *J. Econ. Ent.,* 54:622–624, 966–970, 1961; 55:688–692, 1962; 56:74–76, 350–356, 1963; 57:121–123, 1964.

BOLLWORM

Heliothis zea (Boddie), Family Noctuidae

Since this insect is the corn earworm, and its life history and description have been discussed under that heading (p. 158), it will be necessary only to call attention to the fact that, as a cotton pest, it always has several generations per year. These later generations damage cotton wherever it is grown in the United States with the losses reaching serious proportions in some years. Besides the relatively unimportant eating of the foliage, each larva destroys a large number of bolls and squares (Fig. 188). The bolls may be completely hollowed out, and this damage often occurs so late in the season that it is impossible for the plants to mature another crop. Heavy populations greatly reduce the yield.

When eggs are present and at least four newly hatched larvae are found per one hundred plants, it is time to begin applying insecticides.

Fig. 188. The cotton bollworm, *Heliothis zea* (Boddie): (left) larva in cotton boll and, (right) crawling on stem of cotton. (U.S.D.A.)

Successful control depends on timing the application of dusts or sprays while the eggs are hatching and before the worms enter the bolls.

Recommended insecticides are carbaryl, DDT, endrin, Strobane, toxaphene, malathion, and methyl parathion. Where resistance to DDT and endrin are indicated Azodrin or mixtures of DDT and toxaphene have been effective.

Deep plowing and cultivating are helpful in destroying the overwintering pupal stages in the soil. Early planting, along with early maturing varieties, is a means of avoiding heavy damage. Extremely hot, dry, windy weather is unfavorable to bollworms. Lady beetles and other predators often destroy many eggs and tiny larvae.

References: *Ark. Bul.* 320, 1935; *U.S.D.A. Leaflet* 462, 1960; *J. Econ. Ent.*, 55:143–144, 688–692, 1962; 56:442–444, 1963.

COTTON APHID

Aphis gossypii **Glover, Family Aphididae**

This species is widely distributed in both North and South America, and is considered the most important of several aphids that attack cotton and okra. It is also known as the melon aphid since it is a pest of melons, cucumbers, pumpkins, and squash. Damage, caused by the nymphs and adults removing plant sap, results in stunting of growth, curling of leaves, or death of tiny plants early in the season. Heavy feeding later in the summer causes the curled leaves to fall off before the bolls are mature, thus reducing the yield and grade of cotton. These aphids also excrete honeydew which drops on the open bolls and leaves, and serves as a medium for the development of sooty fungus. Open bolls covered with honeydew contain gummy lint, which is difficult to gin.

Other species of aphids sometimes found on cotton are the cowpea aphid, *Aphis craccivora* Koch, and the corn root aphid, *Anuraphis maidiradicis* (Forbes) (p. 194).

The common aphid varies from pale yellow to light or dark green, with dark leg joints, and black cornicles and eyes (Fig. 293). In the extreme South only parthenogenetic females which give birth to young are found, with over fifty generations often developing throughout the year. In the northern states both sexes occur, and overwintering eggs hatch in the spring, all the progeny being wingless parthenogenetic females that give birth to their young. Repeat generations of the same type of individual occur through the summer, with occasional winged stages developing and flying to other areas. With the coming of cold weather sexual forms are produced which mate, the females depositing the overwintering eggs.

Natural controls consist of aphid lions, syrphid fly larvae, lady beetles,

and other predators; insect parasites, of which *Aphidius* spp. is the most important; diseases; and hot, dry, summer weather.

Nearly all insecticides employed for control of such pests as the boll weevil and bollworm will also kill the natural enemies of the cotton aphid. However, some of these insecticides such as DDT and calcium arsenate will not kill the cotton aphid. When this happens aphid populations increase rapidly. If guthion, malathion, Bidrin, parathion, methyl parathion, trithion, ethion, demeton, diazinon, or Dylox are employed to control other insects on cotton, even if DDT has been added, populations of the cotton aphid are also checked. Many of the chlorinated hydrocarbon insecticides will slow down aphid activity, but they do not control heavy infestations. Adding the proper amount of phorate or Di-Syston to the seed, or as granules in the furrow at planting, is a recommended procedure where systemic control is desirable.

Selection of the best combination of insecticides to control all the pests of cotton should be made in consultation with your local agricultural extension representative.

References: *U.S.D.A. Farmers' Bul.* 1499, 1926; *Leaflet* 467, 1960; *Fla. Bul.* 252, 1932; *J. Econ. Ent.*, 56:326–333, 900–901, 1963.

SPIDER MITES

Order Acarina, Family Tetranychidae

The increased use of organic insecticides for cotton insect control has resulted in higher populations of spider mites owing, at least in part, to the killing of their natural enemies. Damage to the plants results from the removal of sap by the nymphs and adults. This feeding is primarily on the lower surface of the leaves, appearing as tiny white spots. Under heavy infestation this causes the leaves to become entirely gray, curl, turn brown, and drop off. Loss of leaves causes shedding of small bolls and may prevent the lint from developing properly in large bolls. Over two hundred host plants are recorded, including garden and field crops, ornamentals, and weeds.

Some common species attacking cotton are the carmine spider mite, *Tetranychus telarius* (L.); strawberry spider mite, *T. atlanticus* McG.; two-spotted spider mite, *T. urticae* Koch; Pacific spider mite, *T. pacificus* McG.; desert spider mite, *T. desertorum* Banks; tumid spider mite, *T. tumidus* Banks; Schoene spider mite, *T. schoenei* McG.; four-spotted spider mite, *T. canadensis* (McG.); and the brown wheat mite, *Petrobia latens* (Müller).

Spider mites are variable in color, usually of green, yellow, or red shades, with darker pigmented spots. The first instars are six-legged and of a yellow color. Later instars have eight legs, the mature females being

Fig. 189. Pacific spider mite, *Tetranychus pacificus* McG.; a female showing markings when feeding; greatly enlarged. (Courtesy of A. E. Pritchard.)

the larger of the two sexes and usually showing more pigmentation (Fig. 189). The males are recognized by their smaller size and narrow, more pointed abdomen. The green spherical eggs are more often deposited on the undersides of the leaves where most feeding and spinning of delicate webs take place. Hot dry weather is favorable to rapid development, and there may be as many as seventeen to twenty generations and more per year, these overlapping considerably. Many of the mites attacking cotton overwinter in the active stages, often as mature females, but eggs may be found in regions with very mild winters.

Spread of the mites takes place not only by crawling but by transportation with the aid of insects, birds, air currents, and the normal activities of man.

Natural control is from predaceous insects and mites, an important spe-

cies of the latter being *Typhlodromus fallacis* Garman. This mite is easily killed by many of our new chlorinated hydrocarbon insecticides, resulting in greater numbers of plant-feeding species. Heavy rains have a checking effect on spider mite populations.

Chemical control measures are many and their effectiveness varies with the species of mite concerned. The following chemicals are recommended for cotton: ovex, Bidrin, chlorobenzilate, Aramite, demeton, ethion, carbophenothion, malathion, parathion, methyl parathion, Kelthane, tetradifon, phorate, Di-Syston, and sulfur. Higher dosages of sulfur are necessary to control the Pacific mite, the brown wheat mite, and the strawberry mite. At least 40% sulfur incorporated in all dust applications to cotton will control some species of mites and act as a depressant for others. Sulfur is more effective when finely ground and applied at temperatures of 90° F. or above. The best control of brown wheat mite has been with parathion or demeton. Spider mites can be effectively held in check by including low dosages of miticides in all applications of cotton insecticides.

References: *U.S.D.A. Bul.* 416, 1917; *Leaflet* 502, 1962; *Hilgardia,* 22:203–234, 1953; *J. Econ. Ent.,* 46:224–233, 693–696, 1953; 51:710–712, 1958; 57:145–148, 1964.

COTTON FLEAHOPPER

Psallus seriatus (Reuter), Family Miridae

This bug is widely distributed throughout the cotton-producing regions of the United States. Besides cotton, horsemint, evening primrose, croton or goatweed, sage, and numerous weeds are attacked by the fleahoppers.

The piercing-sucking nymphs and adults interfere with normal vigorous growth, cause the death of very young squares or blossom buds, and prevent blooming. The feeding punctures stimulate the plant to produce numerous spindly branches or suckers, indicating that the salivary secretions injected while sap is being sucked are toxic. First feeding is primarily on weeds but as these become less succulent migration to cotton takes place. Rainfall is favorable to their breeding on cotton and when the squaring season is passed, the fleahoppers return to the weed hosts.

The fleahopper overwinters in the egg stage in the stems of the hosts. In early spring these hatch into nymphs that become adults after molting four times. The winged adult bug is $\frac{1}{8}$ inch in length, pale green with tiny black spots (Fig. 190). A generation spans a period of about three weeks with six to eight developing each season. Generations overlap so much they become indistinguishable as the season progresses.

Effective chemical control results by applying a spray or dust containing one of the following: carbaryl, DDT, aldrin, chlordane, dieldrin, endrin, BHC, heptachlor, Dylox, guthion, parathion, methyl parathion, Strobane, Bidrin, toxaphene, or malathion. When spider mites become a

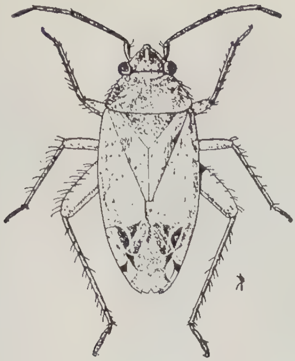


Fig. 190. The cotton flea-hopper. (U.S.D.A.)

problem, 40% or more of sulfur or some other miticide should be added to dust formulations. Host plants containing overwintering eggs can be buried by plowing. This reduces the potential fleahopper population.

References: *S.C. Bul.* 235, 1947; 251, 1928; *Texas Bul.* 339, 1926; 380, 1928; *U.S.D.A. Yearbook of Agriculture,* Plate IV, 1952; *Leaflet* 475, 1960; *J. Econ. Ent.,* 54 : 966–970, 1961.

OMNIVOROUS LEAF ROLLER

Platynota stultana Walsingham, FAMILY TORTRICIDAE

This insect is becoming increasingly important in the United States as a pest of a wide variety of crops, especially in areas where the year-round growing season provides a sequence of crop plants on which to feed. Cotton and alfalfa are favored host plants but celery, lettuce, red pepper, tomato, sugar beet, citrus, rose, carnation, chrysanthemum, aster, and over thirty other plants, in greenhouses and out-of-doors, have also been attacked.

Adults are typical tortricid moths. The female is darker colored than the male (Fig. 191) and may lay over 300 eggs during her life span. Pale green eggs are deposited in masses, usually on the upper leaf surface and primarily during the hours of twilight and dawn. Individual eggs overlap each other like fish scales and the entire mass is cemented together and to the plant with a secretion from the colleterial glands. Hatching occurs in about seven days and the black-headed pale yellow larvae begin making silken ladders on which they move about and feed. The larval habit of concealing itself by rolling a leaf usually begins in the second instar. It takes approximately five minutes to complete the leafrolled nest. Some larvae complete their development in a single nest; others

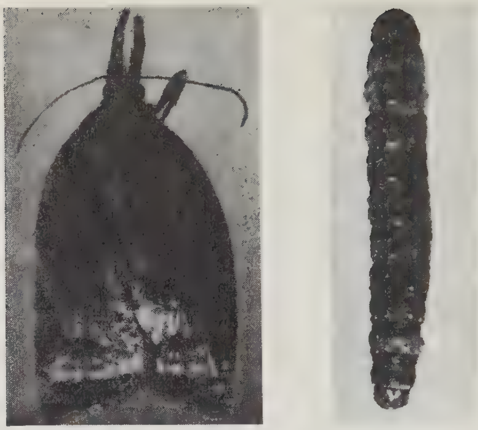


Fig. 191. Adult male moth and fifth instar larva of the omnivorous leaf roller. (U.S.D.A.)

may build six or more. After a total of five larval instars and about twenty-five days pupation takes place within the rolled leaf; a week later adults emerge. This rate of development is based on 80° F.; at higher temperatures the life cycle is completed in less time.

Four parasitic wasps and seven predators were found attacking this pest in California but none was of sufficient importance to effect practical control.

Chemicals that have given satisfactory control are DDT, carbaryl, trichlorfon, parathion, methyl parathion, Zectran alone or in combination with ronnel, and Perthane. Follow the recommendations prepared for the crops affected in your area.

References: *J. Econ. Ent.*, 29:306–312, 1936; 50:59–64, 1957; *Ann. Ent. Soc. Amer.*, 50:251–259, 1957; *Calif. Agr. Exp. Sta. Leaflets* 83, 86, 1964; *Down to Earth*, 20:18–22, 1965.

COTTON LEAFWORM

Alabama argillacea (Hübner), Family Noctuidae

This is a tropical insect not known to survive the winters in the United States. Damage is done by the larvae, which feed on the leaves of the cotton plant and when abundant also destroy the squares and bolls. Adult moths may feed on ripe grapes, peaches, or other fruits. The proboscis is fitted with spines on the tip enabling them to puncture the skin of the fruits.

The brown moths, marked with a few darker, wavy transverse bars on the fore wings, have a wingspread of about 1½ inches (Fig. 192). Each

Fig. 192. Cotton leafworm moths, *Alabama argillacea* (Hübner).

spring they fly in from the tropics and lay their eggs on cotton leaves. These hatch in a few days into pale dingy yellow caterpillars that molt five times. As growth progresses their color varies; some are yellow-green without prominent stripes, others have a broad black stripe with a narrow yellow stripe down their backs. All the caterpillars have four black dots that form a square on the dorsal side of each body segment. They become fully grown in two weeks or more and pupate on the plant, usually inside a leaf fold. Adults emerge several days later and begin the cycle anew. There are three to seven generations per year. Adult migration northward occurs as the season advances, great numbers sometimes reaching Canada.

Many natural enemies help control the leafworm, for example, birds, wasps, ants, spiders, robber flies, predaceous bugs and beetles, mantids, aphid-lions, and several parasitic insects and diseases.

Dusting or spraying with calcium arsenate, carbaryl, BHC, diazinon, endrin, ethion, guthion, malathion, methyl parathion, parathion, methyl trithion, Strobane, or toxaphene will control leafworms.

Where a program is followed for boll weevil control this insect never becomes a problem. The leafworm is sometimes considered beneficial, especially late in the season when its defoliation of the plants, after the crop is made, helps to starve the boll weevils that normally become the overwintering population. Orchardists following a regular spray program are usually not bothered by adult damage to fruits.

References: *U.S.D.A. Leaflet* 468, 1960; *J. Econ. Ent.*, 51:259, 1958; 55:688–692, 1962.

PINK BOLLWORM

Pectinophora gossypiella (Saunders), Family Gelechiidae

The pink bollworm, believed to be a native insect of India, is a serious pest of cotton in many parts of the world. It was first discovered in the United States in Texas in 1917, presumably having come from nearby Mexico where it was found before that date. Heaviest losses occur in

Texas, but it also is present in Arizona, Arkansas, New Mexico, Oklahoma, and Louisiana. Okra is the only other widespread, commercially grown host plant.

Damage is done by the larvae which eat out the seeds in the green bolls and thus reduce the yield, weight, viability, and oil content of the seeds. They also reduce the quantity and quality of the lint. In heavily infested fields many of the bolls are so badly damaged that they are not picked.

The pink overwintering larvae may hibernate in a single seed, or two hollowed-out seeds united by silken threads, in bolls or trash in the field, or at the gin. Pupation takes place in the spring, with adult emergence occurring a week or more later. The adults are small gray-brown moths with narrow wings fringed with hairs (Fig. 193). Each moth lays 100 to 200 oval white eggs, usually in masses, beneath the calyx at the base of the boll. Hatching occurs in about five days, and the new white larvae with

Fig. 193. (Right) the pink bollworm: outline drawing of larva; much enlarged. (Left) the pink bollworm adult; much enlarged. (Busck.)

brown heads eat their way into the squares or bolls, where feeding occurs for ten to fourteen days, after which the fully grown pink larvae, now $\frac{1}{2}$ inch in length, make exit holes and either pupate within the bolls or on the ground. Development from egg to adult requires twenty-five to thirty days in midsummer, and there may be as many as six generations per year in areas with long growing seasons.

Methods of control include destruction of cotton stalks immediately after harvest by special shredders and plowing; heating cottonseed to a temperature of 145° F.; burning gin waste; fumigating gins, warehouses, and seeds; and field application of a dust or spray of DDT or carbaryl, or a mixture of DDT and toxaphene or Strobane. DDT and carbaryl should be applied at the rate of 1.5 to 3 pounds of technical material per acre at

weekly intervals, but only 1.5 pounds are required when used in combination with 2 or 3 pounds of toxaphene or Strobane. Applications should be repeated until most of the bolls are open or the infestation controlled. For best results the cultural controls should be carried out on an area-wide basis with the cooperation of all cotton growers. In regions where there is little winter rainfall and temperatures of 10° F. or lower are expected, the stalks may be left standing in the field, since these conditions favor high mortality of overwintering larvae.

Federal and state quarantines control the movement of cotton and its products, and okra, from all counties in which pink bollworm infestations are found. Since 1913 a federal quarantine has excluded from the United States cottonseed and their hulls from most of Mexico and from all other countries. Sterilized seed and hulls, produced in limited areas of Mexico, may be moved into infested areas of the United States. Imported cottonseed cake and meal containing uncrushed seeds must be fumigated at the port of entry.

To eradicate new or isolated infestations, states may establish zones in which cotton is not to be grown for one to three years, resulting in starvation of the pink bollworm.

References: *U.S.D.A. Farmers' Bul.* 2207, 1965; *Tech. Bul.* 1304, 1964; *Prod. Res. Report* 34, 1960; 73, 1963; *J. Agr. Res.*, 9:343–370, 1917; *J. Econ. Ent.*, 57:148–150, 181–182, 1964.

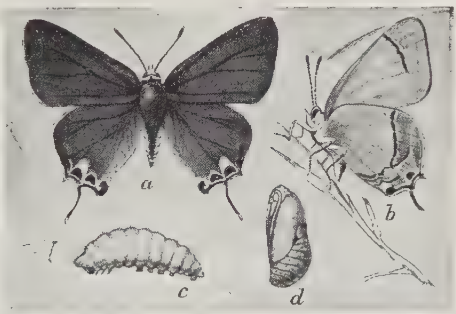


Fig. 194. The cotton square borer, *Strymon melinus* (Hbn.): *a*, adult; *b*, under wing of same; *c*, larva; *d*, pupa; natural size. (Howard, U.S.D.A.)

MINOR PESTS OF COTTON

Cotton Square Borer, *Strymon melinus* (Hbn.), the larva of a small butterfly in the family Lycaenidae (Fig. 194), is occasionally a pest of cotton in Texas and adjacent states. Damage is caused by the larvae boring into and hollowing out the squares. These larvae are slug-like, almost foot-

less, light green in color, and densely pubescent. Both adults and larvae hibernate; egg-laying begins in March, and as many as three overlapping generations may develop, but natural enemies usually keep them checked. The insecticides normally used for boll weevil will prevent injury from the square borer.

Thrips of several species attack cotton. They may at times be more injurious than the fleahopper. Although thrips injury is usually observed on seedling cotton, damaging infestations will sometimes be found on older cotton, especially in areas where vegetables, legumes, and small grains are grown near-by. Common species found on cotton are tobacco thrips, *Frankliniella fusca* (Hinds), and *F. exigua* Hood; flower thrips, *F. gossypiana* Hood, *F. occidentalis* (Pergande), and *F. tritici* (Fitch); bean thrips *Caliothrips fasciatus* (Perg.); onion thrips, *Thrips tabaci* Lind.; and *Sericothrips variabilis* (Beach.).

Both nymphs and adults cause injury with their rasping-sucking mouthparts. The life cycle is completed in about two weeks and overlapping generations occur throughout most of the year where cotton is grown. In some areas thrips are only one of several pests attacking cotton early in the season. Application of many of the insecticides recommended for these other pests will also control thrips. Chemicals giving satisfactory control are aldrin, Bidrin, BHC, chlordane, carbaryl, DDT, dieldrin, endosulfan, endrin, heptachlor, Strobane, methyl trithion, toxaphene, guthion, malathion, parathion, and methyl parathion. The systemic chemicals phorate or Di-Syston may be applied to the seed or as granules in the furrow at planting. Sprays are more effective than dusts for thrips control on seedling cotton. If thrips develop resistance to the chlorinated hydrocarbon insecticides, then change to carbaryl or one of the organo-phosphorus compounds.

References: S. C. *Bul.* 271, 1931; 306, 1938; *U.S.D.A. Leaflets* 516, 1962; *J. Econ. Ent.*, 55:516–518, 1962.

Leafhoppers of several species may damage cotton. Some common large species are *Homalodisca coagulata* (Say) (Fig. 28), *Aulacizes irrorata* (Fabr.), *Oncometopia orbona* (Fabr.), and *Cuerna costalis* (Fabr.) (Fig. 195). In addition small green species in the genus *Empoasca* will attack cotton. When numerous, all species may cause extensive injury with their piercing-sucking mouthparts. Satisfactory control may be obtained with 5% DDT dust or 5% methoxychlor dust applied at the rate of 15 to 20 pounds per acre. Usually no special treatment is necessary when DDT is applied for controlling major cotton insects.

Thurberia Weevil, *Anthonomus grandis thurberiae* Pierce, is a variety of the boll weevil, native to this country and found infesting a species of wild cotton in Arizona. It has spread from this host (*Thurberia* sp.) to cultivated cotton and seems to be increasing in numbers. Only one and a

a *b* *c*

Fig. 195. Three cotton leafhoppers commonly called sharpshooters: *a, Cuerna costalis* (Fabr.); *b, Oncometopia orbona* (Fabr.); *c, Aulacizes irrorata* (Fabr.) (U.S.D.A)

partial second generation occur on wild cotton, but this increases to three generations on cultivated cotton. Control measures advocated for the boll weevil are recommended for this insect.

Stink Bugs attack a wide variety of plants, and several species seriously damage cotton in all areas where it is grown. These species are the conchuela, *Chlorochroa ligata* (Say), the green stink bug, *Acrosternum hilare* (Say), the western brown stink bug, *Euschistus impictiventris* (Stål), the southern green stink bug, *Nezara viridula* (L.) (Fig. 196), and the Say stink bug, *Chlorochroa sayi* Stål. Most damage is done when the cotton plants are fruiting. The piercing-sucking mouthparts are inserted into the bolls and the sap removed from the immature seeds. These punctures cause shedding of small bolls; those more mature are retained but the lint is stained, short, weak, and of little market value. Most species pass the winter as adults and produce one or more generations per year depending on the latitude. Control of stink bugs on cotton has been obtained by the following insecticides: aldrin, BHC, carbaryl, dieldrin, endosulfan, guthion, lindane, methyl parathion, parathion, Strobane, toxaphene, and Dylox. Combination dusts or sprays of DDT plus toxaphene or methyl parathion were also effective in control.

References: *Ariz. Agr. Exp. Sta. Bul.* 140, 1960; *J. Econ. Ent.*, 57:60–62, 1964.

Cotton Stainer, *Dysdercus suturellus* (Herrich-Schäffer), is a bug which punctures cotton bolls with its piercing-sucking mouthparts and interferes

Fig. 196. The southern green stink bug, *Nezara viridula* (L.), nymph. (Morrill, U.S.D.A.)

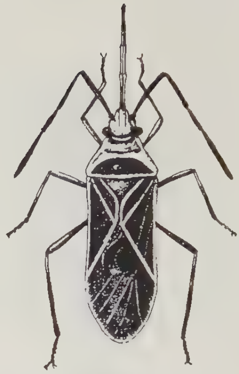


Fig. 197 The cotton stainer. (U.S.D.A.)

with their proper development. It, as well as related species, causes yellow discoloration of the lint in the more mature bolls. As a rule the stainer is of minor importance. A species causing similar injury is the Arizona cotton stainer, *Dysdercus mimulus* Hussey. These bugs belong to the order Hemiptera, family Pyrrhocoridae (Fig. 197). They are controlled by the same chemicals recommended for the major cotton pests.

Yellow-Striped Armyworm, *Prodenia ornithogalli* Guenée, is sometimes a serious pest of cotton and it also feeds on many other plants. It is most abundant in the South where it passes the winter as a pupa and produces several generations per year. The larva is recognized by the paired, dorsal black spots on most body segments and a yellow stripe on each side (Fig. 198). It is a day-feeding species, and recommended control measures are the same as for armyworms (p. 147) and cutworms (p. 153).

May Beetles have been observed to injure cotton in the Southwest. Two species, *Phyllophaga lanceolata* (Say) and *P. cribrosa* (LeC.), have been the most prevalent. Damage is done by the adults defoliating cotton, soybeans, and other crops, and by the larvae feeding on the roots of grasses, especially wheat. The adults are unable to fly because they lack a functional second pair of wings. See white grubs, p. 136, for control measures.

Cotton Leaf Perforator, *Bucculatrix thurberiella* Busck, is the larva of a very small moth that feeds first by mining and later by eating small holes in the leaves. Hot dry climates seem favorable to its development; it has been injurious in parts of Texas, Arizona, New Mexico, and California. Recommended insecticides include the following: carbaryl, carbopheno-

Fig. 198. The yellow-striped armyworm, *Prodenia ornithogalli* Guenée; larva on the boll and adult moths. (U.S.D.A.)

thion, diazinon, dieldrin, Dilan, endosulfan, endrin, guthion, malathion, methyl parathion, methyl trithion, naled, parathion, phosphamidon, Strobane, toxaphene, and Dylox.

References: *U.S.D.A. Agr. Handbook* 290, 1965; *J. Econ. Ent.*, 67–70, 1961.

Salt-Marsh Caterpillar, *Estigmene acrea* (Drury), is a red-to-brown hairy larva, ranging up to 2 inches in length, which devours the foliage of cotton and many other plants. The adult moths have a wingspread of about 2 inches. Wings of the females are white above and yellow below; the males are similar except that the hind wings are yellow both above and

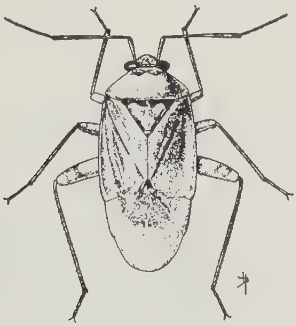


Fig. 199. The western tarnished plant bug, *Lygus elisus* Van.D. (U.S.D.A.)

below. Both sexes have a number of black spots on the wings. The pupae overwinter in cocoons, and there are usually two generations per year. This insect is normally controlled by DDT, toxaphene, carbaryl, diazinon, Dilan, Dylox, endrin, malathion, methyl parathion, parathion, and other insecticides recommended for major cotton pests.

References: *U.S.D.A. Bul.* 44, 1904; *J. Econ. Ent.*, 24:835–838, 1931; 52:1109–1111, 1959; 53:78–80, 1960; 54:1266, 1961.

Plant Bugs cause shedding of cotton squares and young bolls by puncturing and feeding with their piercing-sucking mouthparts. Older bolls are not shed but the lint is discolored and clings to the bur; also, the oil content and germination of the seeds are reduced. Damage to cotton is frequently serious when adjacent alfalfa fields are cut, causing migration of the adults to cotton. The tarnished plant bug, *Lygus lineolaris* (P. de B.) (Fig. 215), is a cotton pest in the southeastern states. Related species are *L. elisus* Van Duzee and *L. hesperus* Knight, which cause damage in the Southwest (Fig. 199). The rapid plant bug, *Adelphocoris rapidus* (Say) (Fig. 216), is widely distributed in the United States and Canada. It frequently is a pest of cotton adjacent to alfalfa, sweet clover, and weedy growths. In the latitude of Utah plant bugs may produce three or four generations per year, each requiring about seven weeks; in southern Arizona and Texas a generation is passed in 30 days or less, and the insects breed most of the year. In cooler climates, the *Lygus* bugs overwinter as adults, *A. rapidus* in the egg stage. Effective chemical control is accomplished with either spray or dust formulations containing one of the following chemicals: aldrin, BHC, Bidrin, carbaryl, chlordane, DDT, diazinon, dieldrin, dibrom, endrin, heptachlor, Dylox, guthion, malathion, methyl parathion, methyl trithion, naled, parathion, Strobane, or toxaphene.

References: *U.S.D.A. Leaflet* 503, 1962; *Agr. Handbook* 313, 1966.

11

Insects Injurious to Leguminous Crops

MEADOW SPITTLEBUG

Philaenus spumarius **(Linn.), FAMILY CERCOPIDAE**

Spittlebugs are widely distributed in North America and have been known for a long time but only in the last two decades have they increased in numbers to a point where serious damage has been noted, especially to such perennial plants as strawberries, nursery, and legume forage crops. The injury occurs when the plant sap is extracted by the piercing-sucking nymphs and adults. Stunting of growth, shortening of internodes, dwarfing, rosetting, general loss of vitality, and low yields are some of the known effects.

The adults resemble robust leafhoppers but can be distinguished from them by stout spines on the hind tibiae and a circlet of spines at the base of each. Considerable variation in the color pattern exists, some are light tan, others mottled with dark brown, and still others almost black (Fig. 200). These have been called color varieties; field collections have shown that copulation between them does occur, and inheritance is undoubtedly involved in the variation. The eggs, white at first, then turning a light

Fig. 200. Meadow spittlebug adults, showing color varieties.

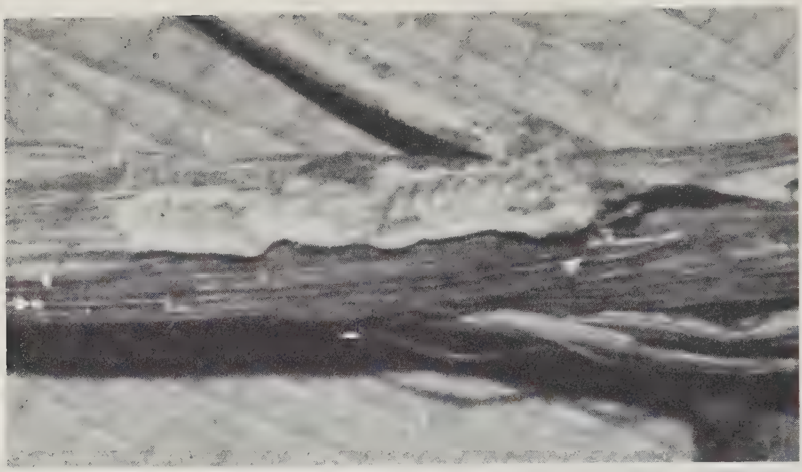


Fig. 201. Egg mass of the meadow spittlebug. (Courtesy of D. D. Ahmed.)

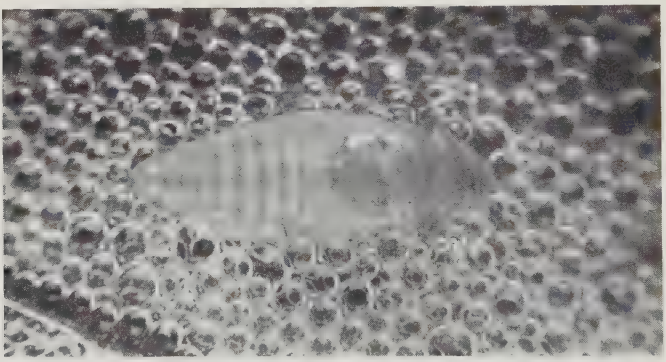


Fig. 202. Spittlebug nymph in spittle mass. (Courtesy of D. J. Borror.)

brown color, are laid in rows between the sheaths and stems (Fig. 201) or in cracks of the stems or stubble of plants near the soil surface. The yellow nymphs pass through five instars, becoming tinged with green as they approach the adult stage (Fig. 202). The normal excretion from the alimentary canal is mixed with air, forming the spittle mass inside which all nymphal instars must develop (Fig. 203).

The overwintering eggs begin hatching about the middle of April in the latitude of Columbus, Ohio, reaching the adult stage in about 45 days. Adults are present throughout the summer feeding on a variety of plants, but their damage is not as evident as that of the nymphs in the spittle masses. Adults migrate by jumping or by flying short distances. Whenever a crop of hay is cut they migrate into adjacent areas causing a noticeable

Fig. 203. Spittle mass, greatly enlarged. (Courtesy of Roger M. Thomas.)

increase in numbers. Egg-laying begins about the first of September and continues until the females are killed by cold weather.

Plowing under any crop that harbors overwintering eggs will eliminate the possibility of nymphal damage to the new planting on that soil.

The need for chemical control in the spring can be predetermined by surveying the crop in autumn. An average of one adult spittlebug per sweep of a standard insect net in September will result in one nymph per stem in the spring. Control measures are usually justified where nymphal populations are at this level or higher.

Chemicals most widely used for controlling nymphs on ornamentals, forage, and strawberries are carbaryl, BHC, diazinon, endosulfan, malathion, methoxychlor, guthion, and lindane. BHC and lindane have limited application because they tend to accumulate in the soil and produce off-flavors in root crops and fruits. Although considered by some as outdated, a spray containing rotenone powder (4%) at the rate of 5 pounds in 100 gallons of water plus a spreading agent gives good control of spittlebug

nymphs on strawberries without any residue problems. At least one or two additional sprays of this chemical will be required if the infestation is heavy.

Except for rotenone only one insecticide application is needed if it is made at the proper time. Because plant growth and egg hatching are correlated somewhat with prevailing temperatures it is suggested that the chemical be applied when red clover and alfalfa reach a height of about 6 and 8 inches respectively. For many areas this will be about May 1. Chemicals like BHC and lindane will give good control even if applied when plant height is 2 inches and the eggs have not hatched. Follow the recommendations prepared for your area by the extension entomologist.

For strawberry plantings or new stands of alfalfa or red clover, treating early in September with DDT or methoxychlor at 1.5 pounds per acre kills the adults before many eggs are laid. If properly timed, it usually eliminates the need of a spring treatment for killing nymphs. Methoxychlor is favored over DDT if there is a possibility of using the field for fall pasture. DDT treated fields should not be pastured until the following year.

References: *J. Econ. Ent.*, 39:299–305, 1946; 43:905–908, 1950; 44:163–166, 289–293, 1951; 52:240–242, 904–907, 1959; 53:960–961, 1960; 55:184–188, 718–722, 828–830, 1962; *Ohio Res. Bul.* 741, 1954; *U.S.D.A. Leaflet* 514, 1962.

ALFALFA WEEVIL

Hypera postica (Gyllenhal), Family Curculionidae

The alfalfa weevil is a European insect that appeared in Utah about 1904 and has since spread into all the western states; in 1951 it was found in Maryland and is now rapidly spreading southward and westward throughout the eastern and central states wherever alfalfa is grown.

Damage is caused by the adults and larvae feeding on the growing tips, leaves, and buds of alfalfa, lowering its value as a hay crop or preventing profitable production of seed. The insect is essentially a pest of first-growth alfalfa but the second growth is also attacked. Other clovers and vetch are sometimes slightly damaged.

The adult is a snout beetle about $\frac{3}{16}$ inch long, varying in color from brown to black with faint lighter markings (Fig. 204). Overwintering occurs primarily in alfalfa fields and chiefly as adults. With the coming of warm spring temperatures the females begin depositing tiny oval lemon-yellow eggs which darken as hatching approaches. At first the eggs are deposited in fragments of dead stems on the ground but after spring growth takes place egg-laying is gradually shifted to the alfalfa stems. They are placed in clusters of twenty-five or more with each female averaging about 400 eggs, most of which are laid in April and May. Hatching generally begins

Fig. 204. The alfalfa weevil, *Hypera postica* (Gyll.): adults, larvae, pupa, eggs, and greatly enlarged antenna.

in April, but larvae do not become numerous until late May or early June or about the time that first-growth alfalfa produces buds. Each larva molts three times and attains a length of $\frac{3}{8}$ inch at maturity, when the head is black and the body is green with a white stripe along the middle of the back and a fainter parallel stripe on each side. By May 15 some larvae complete their growth and spin lacelike cocoons on the plant or on the ground in which transformation to pupae occurs. One or two weeks later the new adults emerge, feed throughout the summer and go into hibernation with the coming of cold weather. In the lower valleys of western Colorado it is reported that some weevils become sexually mature and lay eggs before cold weather arrives. These fall-laid eggs do not hatch until spring. Usually only one generation occurs per year but in some areas a partial second generation sometimes develops.

Like all insects this weevil is limited by all the factors in natural control. An introduced species of ichneumonid wasp, *Bathyplectes curculionis* (Thomson) (Fig. 205), attacks the larvae of the alfalfa weevil, and in some areas approximately 90% parasitism occurs when the first crop of alfalfa reaches the flower-bud stage.

Cultural and mechanical control measures are suggested which will maintain a dense vigorous stand; the first and second hay crops should be cut when most plants are in the bud stage, the field mowed clean, and the hay removed as soon as it is cured.

When 50% of the plants show feeding injury or when the larval count reaches twenty-five per sweep of an insect net, it is time to apply chemical control measures. Recommended chemicals for spring treatment are mala-

thion, methoxychlor, diazinon, guthion, and parathion. Late fall or winter treatment to kill hibernating weevils has merit providing a chemical can be found that is effective and does not contaminate the forage in the spring.

References: *U.S.D.A. Farmers' Bul.* 1930, 1943; *Leaflet* 368, 1965; *J. Econ. Ent.*, 46:178–179, 1953; 50:810–813, 1957; 52:663–666, 1959; 55:718–722, 747–749, 1962; 57:167–168, 299–300, 1964; *Va. Agr. Exp. Sta. Bul.* 502, 1959; *W. Va. Agr. Exp. Sta. Cir.* 104, 1958; *Conn. Agr. Exp. Sta. Bul.* 621, 1959; *Calif. Agr. Exp. Sta. Ext. Cir.* 85 and 86, 1964.

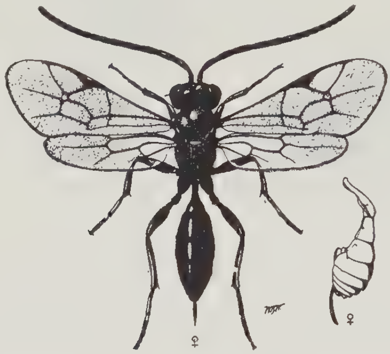


Fig. 205. *Bathyplectes curculionis* (Thomson), a larval parasite of the alfalfa weevil. (Right) side view of abdomen. (Walton, U.S.D.A.)

EGYPTIAN ALFALFA WEEVIL

Hypera brunneipennis **(Boheman), FAMILY CURCULIONIDAE**

This weevil was discovered in the United States near Yuma, Arizona, in 1939, and has spread over much of southern California and other adjacent areas where clover and alfalfa are grown.

The appearance, life history, and habits of this weevil are similar to those of *H. postica*. Adults estivate during the summer months and begin to appear in alfalfa fields in December. Larvae are abundant from February to April. During this period, severe damage may result to the growing tips as well as skeletonizing of entire plants. The weevil is a problem during the first cutting although damaging populations may persist until the time of the second cutting.

When the larval count reaches twenty-five per sweep of an insect net chemical control is usually justified. Apply methoxychlor, malathion, parathion, or methyl parathion at dosages recommended for your area.

References: *J. Econ. Ent.*, 48:297–300, 1955; *Calif. Agr. Exp. Sta. Leaflets* 85, 86, 1964.

SPOTTED ALFALFA APHID

Therioaphis maculata (Buckton), FAMILY APHIDIDAE

The spotted alfalfa aphid, native to the Middle East, was accidentally introduced into New Mexico in 1954 and subsequently has spread over most of southern and central United States. It is especially destructive to alfalfa grown west of the Mississippi River, particularly in the states of Arizona, California, and Nevada. To a much lesser extent the aphid will feed on some clovers and other forage legumes.

Fig. 206. Winged and wingless adults of the spotted alfalfa aphid. (Courtesy of Celeste Greene and Ray F. Smith, Calif. Agr. Exp. Sta.)

Damage results from both nymphs and adults sucking sap from the leaves and stems of the host plants. The first evidence is seen as whitening of the leaf veins; curling, stunting, and yellowing follow, and under heavy infestation the plant will die. In addition, the aphids excrete copious quantities of honeydew, which serves as a medium for the development of sooty fungus; this condition complicates harvesting procedures and lowers the quality of hay.

The aphid is about $\frac{1}{16}$ inch long and pale yellow, with six or more rows of spiny black spots on the dorsal side of the abdomen (Fig. 206). Winged forms have smoky areas along the wing veins.

In warmer climates reproduction is parthenogenetic throughout the year and each female may give birth to over 140 nymphal aphids. The nymphs pass through four instars and mature in one to two weeks when temperatures are high and in three to four weeks when cool weather prevails. There may be twenty or more generations each year. In colder regions sexual forms may develop in autumn, and after mating the females deposit the overwintering eggs.

Natural control from lady beetles, syrphid fly larvae, lacewing larvae,

big-eyed bugs (*Geocoris* sp.), minute pirate bugs (*Orius* sp.), damsel bugs, parasitic wasps, and fungus diseases often keeps populations of this aphid checked. Three introduced parasites, *Praon palitans* Muesebeck, *Aphelinus semiflavus* Howard, and *Trioxys utilis* Muesebeck are contributing to control in areas where they have been released. Growing aphid-resistant varieties such as Washoe, Lahontan, Moapa, or Sonora is a recommended procedure, especially in areas where the aphids have developed resistance to the organophosphorus insecticides.

At times it will be feasible to apply insecticides to check a rapid increase in aphid populations. Treatment is necessary in seedling plantings where one or more aphids are found per plant and in older fields when a count in various areas averages twenty to forty aphids per stem. Parathion, malathion, diazinon, trithion, demeton, and phosdrin are effective control chemicals. Di-Syston and phorate will give protection when used as a seed treatment.

References: *U.S.D.A. Leaflet* 422, 1965; *Hilgardia,* 24:93–117, 1955; 28:647–684, 1959; *J. Econ. Ent.,* 48:668–671, 1955; 50:352–356, 805–807, 817–821, 1957; 52:136–141, 714–719, 1959; 53:89–94, 234–238, 655–659, 1960; 54:1144–1147, 1961; 55:292–294, 900–904, 1962; 56:84–85, 1963; 57:71–76, 1964; *Calif. Agr.,* 17, June, 1963.

CLOVER LEAF WEEVIL

Hypera punctata (Fabr.), Family Curculionidae

This weevil, a native of Europe, has long been present in the United States and is now well established in most areas where clover and alfalfa are grown. Besides various clovers and alfalfa the weevils are also known to feed on soybeans, snap beans, and occasionally the leaves of timothy, wheat, and corn. Damage is caused by the larvae and adults devouring the foliage.

The adult (Fig. 207) is a large, brown snout beetle with indistinct stripes

Fig. 207. The clover leaf weevil, *Hypera punctata* (Fabr.); adult and larva. (U.S.D.A.)

Fig. 208. Larva of the clover leaf weevil on food plant. (Cornell Agr. Exp. Sta.)

formed by light-colored pubescence. It varies in size but averages about $\frac{1}{4}$ inch in length. The yellow oval eggs are deposited in various places about the host plant, usually in autumn. A few weevils overwinter and deposit eggs during mild periods in winter or early spring. Most eggs hatch in the fall, but some remain through the winter. The young green larvae from fall-hatched eggs feed throughout the winter on mild days, becoming fully grown in late April of May. At this time they are almost $\frac{1}{2}$ inch long, light green with a pale stripe down the middle of the back (Fig. 208). Pupation takes place within an oval, net-like cocoon just beneath the surface of the soil or in debris near the base of the plants. About eleven days later the new adults emerge, feed for a short period, and become inactive most of the summer, then oviposit in the fall. There is commonly only one generation each year, but under exceptional weather conditions a second generation may develop and produce weevils before cold weather arrives. These weevils overwinter and deposit their eggs in the spring.

The larvae are subject to the attacks of a fungus, *Empusa sphaerosperma* Fres. Warm temperatures and high humidity favor the development of the fungus. In some areas parasitization of weevil larvae by the ichneumonid wasp, *Biolysia tristis* (Gravenhorst), has reached 90%. Both these natural control agents usually make chemical control measures unnecessary.

Should chemical control be deemed necessary, apply malathion or methoxychlor at the rate of 1 pound per acre. Fall treatment with DDT or methoxychlor for adult spittlebugs has also reduced clover leaf weevil populations.

References: *U.S.D.A. Farmers' Bul.* 1484, 1949; *Cornell Agr. Exp. Sta. Bul.* 411, 1922; *J. Econ. Ent.*, 43:438–443, 1950; 47:927–928, 1954; 51:195–198, 55:831–833, 1962.

LESSER CLOVER LEAF WEEVIL

Hypera nigrirostris (Fabr.), Family Curculionidae

Supposedly indigenous to Europe, this weevil was introduced into North America about 1875. Since then it has spread throughout most of the regions where the favorite host, red clover, is grown. Other clovers and alfalfa are hosts of lesser importance. Damage is caused by both larvae and adults devouring the leaves, stems, and buds. (see Fig. 208).

The adult is scarcely more than $\frac{1}{8}$ inch in length, dark greenish yellow with faint golden stripes on the wing covers, and of more slender form than the clover leaf weevil. Hibernating adults become active in the spring and begin depositing eggs, usually in or on stems and leaflets, from late March to May, depending on the season and latitude. Hatching occurs in approximately two weeks and the white-to-tan, curved-bodied larvae with brown heads feed almost a month, and pass through four instars, then spin cocoons on the ground or on the plant and transform to pupae. New adults emerge in seven or more days and, after a few weeks' activity, estivate until cold weather, then pass the winter as hibernating adults. One generation per year is typical but in some regions there is a partial second generation; where this occurs, oviposition may begin as late as September.

Larvae and pupae are killed by *Empusa sphaerosperma* Fres. Several parasites have been observed attacking this pest with the braconid, *Bracon mellitor* Say, being the most numerous.

Chemical control is suggested only on seed clover when the infestation is heavy. Employ chemicals recommended for your area.

References: *U.S.D.A. Bul.* 85, 1911; *J. Econ. Ent.*, 44:785–791, 1951; 49:542–544, 1956; 50:224, 1957; *Ohio Agr. Exp. Sta. Res. Bul.* 956, 1963.

CLOVER HEAD WEEVIL

Hypera meles (Fabr.), Family Curculionidae

This species was first collected in North America at Rockaway Beach, N. Y., in 1907. It infests the heads of various clovers, particularly crimson, and feeds among the florets, lowering seed production. It also has been reported as skeletonizing bean foliage. In appearance and size it is about the same as the lesser clover weevil. Suggested control chemicals are: malathion, methoxychlor, parathion, guthion, and diazinon. Follow recommendations prepared for your area.

CLOVER SEED WEEVIL

Miccotrogus picirostris (F.), Family Curculionidae

The clover seed weevil, a pest of European origin, was found in the Pacific Northwest in 1929 and in Minnesota in 1947. Tiny gray adults overwinter and move into clover fields, especially alsike, as flowering

begins. The female oviposits inside developing seed pods and on hatching the larvae consume the seeds. Although adults cause some injury by their feeding punctures, the damage to the seeds by the larvae is the more important injury.

A population of sixty weevils per twenty sweeps of an insect net (12 inches in diameter) would cause an expected loss of 30 to 60 pounds of seed per acre.

Excellent control has resulted by applying one of the following insecticides: DDT, dieldrin, or heptachlor. One application made at night when 3% of the crop is in bloom will effectively control this weevil, lygus bugs, and the alfalfa plant bug as well. Proper timing of the application is important in successful control. The night application is to avoid killing pollinating insects. If a second treatment is deemed necessary, use methoxychlor or toxaphene and apply at night even though these chemicals are not as hazardous to bees. Do not feed the crop remnants to livestock.

References: *J. Econ. Ent.,* 27:1103–1104, 1934; *Proc. N. C. Branch Ent. Soc. Amer.*. 10:53, 1955.

SWEET CLOVER WEEVIL

Sitona cylindricollis **Fahraeus, Family Curculionidae**

This weevil was first recorded in Canada in 1927 and in the United States in 1934. In North America it is found from Maryland to Utah and northward into the Canadian provinces. Damage is caused by the adults eating stems of tiny seedlings and crescent-shaped areas from the leaves, and the larvae feeding within or on the nitrogen-fixing nodules of the rootlets and roots. When abundant, the adults may completely destroy seedling sweet clover in the spring. Other host plants, seldom attacked, are alsike clover, alfalfa, and black medic.

The adult is a dark gray snout beetle about $\frac{3}{16}$ inch long. This stage hibernates in the upper inch of soil and crop remnants. In the spring the weevils become active, and egg-laying may begin by the middle of March and continue into June. The eggs are dropped on the soil and a single female may deposit over 1700 during her life span. They are oval pearly white tinged with yellow at first, and in twenty-four hours become black in color. Hatching occurs in one week or more, depending on the temperature, and the tiny white legless larvae burrow into the soil and feed on the roots for thirty to forty days. Following the fourth larval instar pupation occurs; after a period of seven to twelve days the new adults emerge, thus completing the cycle in forty-five to seventy days. There is only one generation per year.

Cultural and mechanical control measures consist of shallow surface tilling in the summer after the hay crop is removed, rotating crops, making

new seedings some distance from old plantings, and plowing old plantings as a green manure crop. If the last operation is done after May 15 in Ohio, it effectively destroys as high as 85% of the new generation while in the egg or larval stages.

Chemical control measures are directed toward killing the overwintering adults that migrate from old plantings and destroy new seedling sweet clover. This is done by treating the new seedlings with one of the following chemicals: chlordane, toxaphene, or DDT. Apply just as the seedlings are beginning to appear. Sweet clover is grown primarily as a green manure crop and there should be no residue problems involved. If the crop is to be grown for hay or pasture check with your extension entomologist for the control recommendations.

References: *Can. Dept. Agr. Pub.* 72, 1948; 943, 1955; *Purdue Exp. Sta. Cir.* 369, 1951; *Minn. Agr. Ext. Folder* 180, 1954; *Ohio J. Sci.*, 53:105–112, 1953; *Ann. Ent. Soc. Amer.*, 56:831–835, 1963; *J. Econ. Ent.*, 45:316–319, 1952; 56:716–717, 1963.

CLOVER ROOT CURCULIOS

Order Coleoptera, Family Curculionidae

The clover root curculios, *Sitona hispidula* (Fabricius) (Fig. 209) and *S. flavescens* Marsham, are widely distributed in North America and attack various clovers, alfalfa, and other leguminous plants. Adults are leaf feeders and the larvae feed within or on the nodules and roots, frequently girdling the tap root. It is thought that root damage favors the development of bacterial wilt in alfalfa.

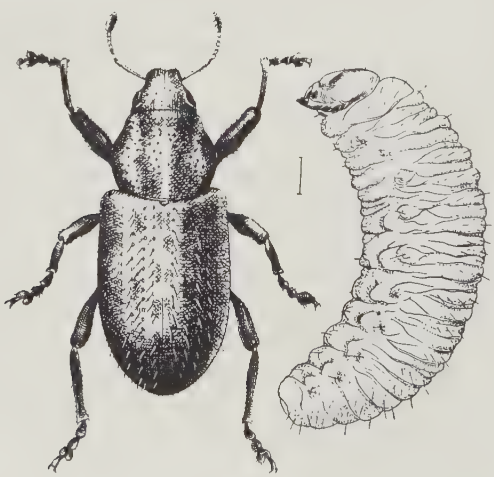


Fig. 209. The clover root curculio, *Sitona hispidula* (F.); adult and larva. (U.S.D.A.)

Both species resemble the sweet clover weevil in habits, size, and life cycle. Overwintering, however, occurs in both the adult and egg stages. Spring laid eggs hatch in one week, whereas fall laid eggs hatch the following spring. New adults emerge in June and July and live nearly one year.

Effective control chemicals are chlordane, dieldrin, and heptachlor. On forage they cause residue problems and their use is limited. Perhaps further research will show that some of the chemicals recommended for controlling alfalfa weevil can be employed to control these weevils should the need arise.

References: *U.S.D.A. Bul.* 85, 1910; 649, 1915; *Ann. Ent. Soc. Amer.*, 56.831–835, 1963; *J. Econ. Ent.*, 23:334–342, 1930; 27:807–814, 1934; 48:184–187, 1955; 52:1155–1156, 1959; 55:906–908, 1962.

COWPEA CURCULIO

Chalcodermus aeneus Boheman, Family Curculionidae

One of the major insect pests of cowpeas, this curculio also attacks string beans, lima beans, strawberries, young cotton seedlings, and several other plants. It is a native insect, most abundant in the South but found as far north as Iowa.

Damage to cowpeas results from the larvae feeding within the developing seeds. This destroys their value as human food and reduces their value as seeds for planting or for feeding to livestock. Early season damage to beans and peas may be severe and cotton seedlings are often destroyed, especially in plantings where cotton follows cowpeas in the crop rotation.

Overwintering adults emerge from hibernation in early summer and deposit their eggs in feeding punctures as the cowpeas begin to form.

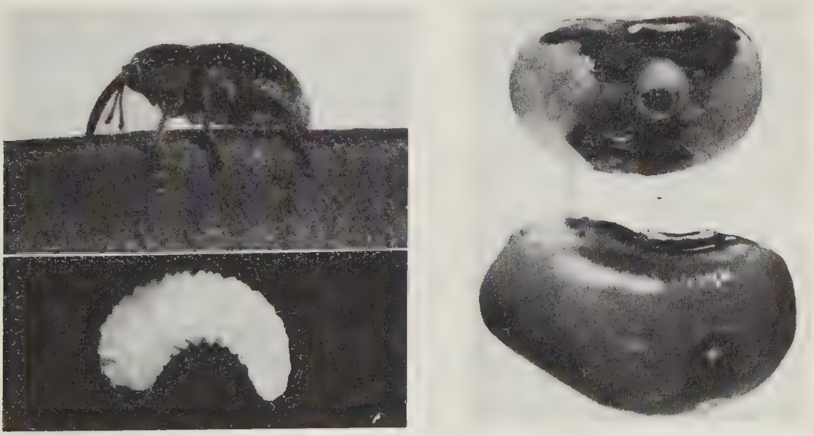


Fig. 210. (Left) the cowpea curculio, *Chalcodermus aeneus* Boheman; adult and larva; (right) larva in seed and egg on seed. (Arant, Ala. Agr. Exp. Sta.)

Hatching occurs in about three days and the white curved larvae feed and molt three times until fully developed, requiring almost a week, after which they leave the cowpeas and crawl in the soil. Pupation follows and the new adults emerge approximately seventeen days later (Fig. 210). The entire life cycle from egg to adult may be completed in about one month. Two generations per year are produced in Alabama, only one in the latitude of Virginia.

Migration of the insect is primarily by crawling. Therefore rotation of crops and sanitation measures should be of value in control. Chemical control is accomplished by spraying when the first pods are beginning to form and two to four applications may be necessary at approximately five day intervals. Chemicals that have given or show promise for control of this pest are methoxychlor, toxaphene, DDT, carbaryl, endosulfan, endothion, and guthion.

References: *Ala. Agr. Exp. Sta. Bul.* 246, 1938; *Va. Agr. Exp. Sta. Bul.* 409, 1947; *J. Econ. Ent.*, 42:856–857, 1949; 56:733–736, 1963.

CLOVER SEED CHALCID

Bruchophagus platyptera **(Walker), FAMILY EURYTOMIDAE**

Although many of the tiny wasps in the superfamily Chalcidoidea are beneficial parasites, some are pests. This one is a seed destroyer. It is one of the most important pests encountered in the production of alfalfa and clover seeds; where seed production is not the goal, the injury is negligible. The insect is generally distributed but is of major proportion in the western and southwestern states where alfalfa and various clovers are grown for seed.

The adult is a tiny black-bodied wasp with four membranous wings (Fig. 211). It appears in the field in early summer and infests the early-blooming host plants by laying eggs in the developing seeds. The white legless larvae devour the inside portion of the seed, change to pupae, and emerge as new adults in approximately thirty to forty days. This is repeated throughout the growing season with one to three generations developing per year, depending on the latitude. All developmental stages occur inside the infested seeds. Larvae overwinter within the harvested seeds or those that fall to the ground during harvest of the host plants. Infested seeds from volunteer host plants along fence rows and similar habitats also serve as hibernation quarters.

Any practical sanitation measure that will help reduce the overwintering population will be of value in controlling this pest. Cooperative community effort is desirable in this type of control program. Plowing, harrowing, and disking in the winter are farm operations designed to bury infested seed or cause it to mold and decay. Fumigation or other treatment

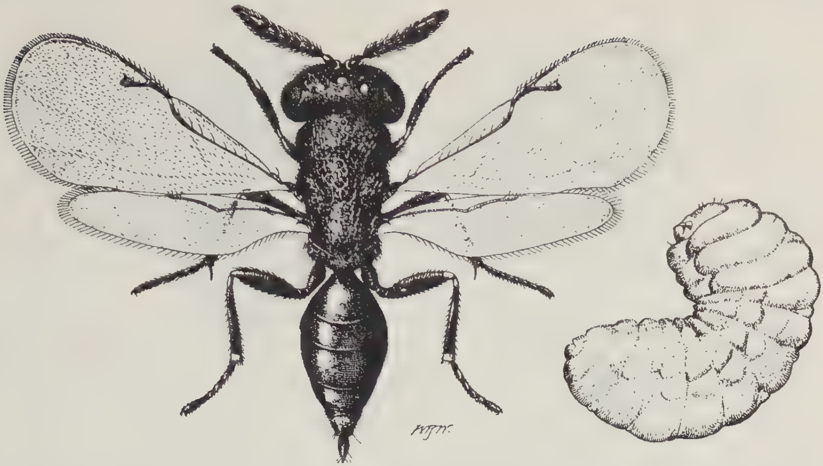


Fig. 211. The clover seed chalcid, *Bruchophagus platyptera* (Walker). (Walton, U.S.D.A.)

of infested seeds is also necessary (p. 573). Badly infested seed crops should be utilized as hay rather than left in the field to add to the infestation. Insecticides have not been highly effective in control and many of them also kill the pollinators.

Several small wasps parasitize the clover seed chalcid and are often quite important in reducing damage.

References: *U.S.D.A. Farmers' Bul.* 1642, 1931; *Wash. Agr. Exp. Sta. Bul.* 587, 1958; *J. Econ. Ent.*, 57:105–110, 1964.

CLOVER ROOT BORER

Hylastinus obscurus (Marsham), Family Scolytidae

The clover root borer is an important pest of red and mammoth clovers. Introduced into the United States from Europe sometime before 1878, it was first reported attacking clover in western New York and since has spread to all parts of northern United States and southern Canada, wherever red clover is an important crop. It has also been recorded feeding on alsike, crimson, and sweet clovers, alfalfa, vetch, garden peas, and field beans, but is of little importance on these hosts.

The roots of clover become infested during the spring of the crop year and damage is most apparent about the time of harvest of the first cutting for hay. The larvae tunnel within and throughout the roots, often killing the plant. Many infested plants are pulled out by the mower during cutting and others remain so weakened that they make little new growth. Such conditions result in a reduced second crop of hay or reduced seed yields.

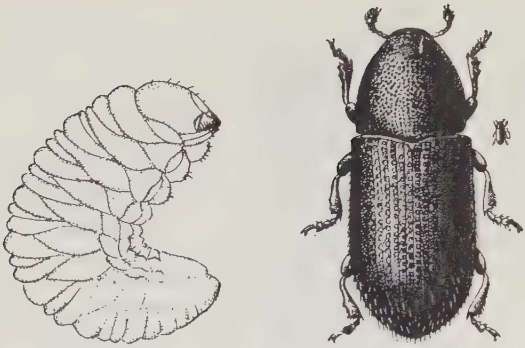


Fig. 212. Larva and adult of the clover root borer. Small figure extreme right is adult natural size. (U.S.D.A.)

Where this pest is abundant root rot and virus diseases are also more prevalent. An average of $1\frac{1}{2}$ borers per root reduces hay yields $5\frac{1}{2}\%$.

Adult clover root borers are roughly $\frac{1}{8}$ inch in length (Fig. 212), varying from light red-brown to darker shades as they age. This stage overwinters in the roots of old clover and in the spring emerges and flies to new clover and deposits oval white eggs in the roots. These hatch into legless, curved, cream white larvae with straw-colored head capsules. Pupation occurs in the roots from July to September, with the pupal period lasting ten or more days. There is but one generation per year.

Control can be accomplished by a late fall or late winter surface application of aldrin, dieldrin, or heptachlor at the rate of $1\frac{1}{2}$ pounds of actual chemical per acre. The dosage may be reduced by at least one-half if clover is band-seeded along with a fertilizer-insecticide mixture. If residue problems result from the surface application, employ only the treatment at seeding time.

References: *U.S.D.A. Dept. Bul.* 1426, 1926; *Cornell Univ. Memoir* 376, 1961; *Ohio Agr. Exp. Sta. Bul.* 827, 1959; *J. Econ. Ent.*, 47:327–331, 1954; 48:190–191, 1955, 50:255–256, 1957; 51:491–492, 1958; 53:449–450, 865–867, 1960; 54:631–635, 1058–1059, 1961.

CLOVER APHID

***Nearctaphis bakeri* (Cowen), Family Aphididae**

In the Pacific Northwest extensive damage has been done at various times by this aphid. It is generally distributed north and west from Oklahoma but has been of the first magnitude only in the region first indicated. Red and alsike clovers are the common hosts attacked.

Serious injury results when great numbers of the piercing-sucking nymphs and adults remove plant sap; this causes stunting and irregular growth,

Fig. 213. The clover aphid, *Nearctaphis bakeri* (Cowen): (left) spring migrant; (right) stem mother. (Idaho Agr. Exp. Sta.)

particularly to the growing tips as well as reduced seed yields. These aphids also excrete great quantities of honeydew that causes the seeds to adhere in pellets, thus lowering their market value. Transmission of viruses causing alfalfa and bean mosaics is attributed to this aphid.

Overwintering eggs are found on apple and related woody plants. As the buds begin to open in the spring the eggs hatch into wingless, parthenogenetic, ovoviviparous females (Fig. 213), that produce succeeding generations of similar individuals, after which winged forms appear and fly to the clover plants. Here repeated generations of wingless and sometimes winged individuals develop throughout the summer. With the advent of cool autumn weather, the winged fall migrants develop and fly back to apple and related hosts, where both males and females are produced and, after mating, the overwintering eggs are deposited.

Natural control from lady beetles, syrphid fly larvae, aphid lions, parasitic wasps, and fungus diseases usually keeps this aphid checked.

At times chemical control can be justified. Some insecticides that kill aphids are parathion, trithion, guthion, diazinon, demeton, naled, phosphamidon, phorate, mevinphos, malathion, and TEPP. Considering the degree of aphid control, safety to pollinators, and safety to parasites and predators the best insecticides are trithion, phorate, phosphamidon, and methyl trithion plus trithion.

References: *U.S.D.A. Farmers' Bull.* 1128, 1926; *Mont. Bul.* 484, 1953; *J. Econ. Ent.*, 53:113–115, 1012–1015, 1960; 54:414–416, 1961; 55:460–462, 1962.

VETCH BRUCHID

Bruchus brachialis Fahraeus, Family Bruchidae

Widely distributed throughout the world, this insect is supposed to be native to Europe. It was first discovered in New Jersey in June, 1930,

by L. J. Bottimer. Since then it has been found in most of the eastern coastal states, some of the Gulf Coast states, and in a limited area in Oregon, Washington, and Illinois.

The bruchid attacks only the developing seeds in the pod, often entirely destroying them. Hence it is only important from the standpoint of seed production, since vetch for forage is little damaged. Observations indicate that it attacks only plants in the genus *Vicia*. Breeding does not occur in dry seeds in storage.

The adult is about $\frac{1}{8}$ inch in length, brown-black, with irregular spots of white pubescence. This stage emerges from hibernation in April, May, and June, depending on the prevailing temperatures, and begins to deposit pale yellow eggs on the pods of the host plant. As many as 42 eggs have been found on a single pod. Hatching occurs in approximately one week, and the white legless larvae enter the pods and then the seeds. Development continues for two weeks, the larvae passing through four instars, with pupation taking place within the seeds. Five days later the new adults begin emerging. Only one generation occurs per season.

Fumigation of all harvested seeds in sacks will kill both emerged and unemerged adults. Use the fumigants recommended for control of stored-product pests (p. 573). Limiting movements of infested hay to uninfested areas is a means of checking spread.

The following chemicals are recommended for controlling this pest on seed crops only: DDT, methoxychlor, malathion, and naled. Two applications twelve days apart, beginning as the first pods appear, have greatly reduced the number of infested seeds at harvest.

References: *J. Agr. Res.* 46:739–751, 1933; *J. Econ. Ent.*, 30:621–632, 1937; 44:993–994, 1951; 52:955–957, 1959; 53:555–558, 1960.

LEAFHOPPERS

Order Homoptera, Family Cicadellidae

Leafhoppers comprise an important group of little noticed sap-sucking insects that cause great damage to a wide variety of crops. Their feeding by means of piercing-sucking mouthparts causes spotting, yellowing, leaf-curling, stunting, and browning of the foliage, depending on the species. Sometimes leafhoppers are responsible for transmitting the organisms causing virus diseases in plants.

Potato Leafhopper, *Empoasca fabae* (Harris), is one of the most important hoppers attacking alfalfa in the eastern half of the United States. It occurs throughout the country with the possible exception of the Northwest. Besides alfalfa, it has been found living on nearly two hundred other kinds of plants, with other forage legumes, potatoes, beans, cowpeas,

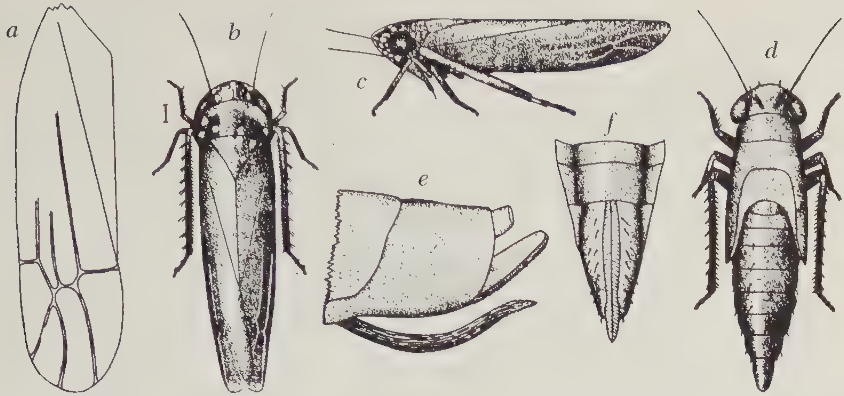


Fig. 214. The potato leafhopper, *Empoasca fabae* (Harris). *a*, enlargement of wing; *b*, dorsal view of adult; *c*, side view of adult; *d*, dorsal view of nymph; *e*, side view of ♀ abdominal tip; *f*, ventral view of ♀ abdominal tip. (Utah Agr. Exp. Sta.)

and deciduous nursery stock the most seriously damaged. The feeding of this leafhopper on alfalfa causes yellowing and dwarfing of the foliage and, in heavy attacks, severe wilting, resulting in lower yield, quality, and stand.

The adult is a pale green, wedge-shaped insect about $\frac{1}{8}$ inch long (Fig. 214). It is very active, jumping or flying when disturbed. Both nymphs and adults can run backwards or sideways as rapidly as they move forward. The females deposit slender white eggs within the stems and larger veins of the leaves. In summer hatching occurs in six to nine days and the pale green nymphs molt four times before they become fully grown and transform to winged adults. Soon after the adults appear mating occurs, followed by egg-laying. The period from egg to adult is about three weeks in warm summer temperatures. There are several generations per year and these greatly overlap. The potato leafhopper has not been found overwintering north of the Gulf states where it breeds throughout the year; it migrates northward with the warm spring winds annually. In the latitude of Washington, D.C., the first adults usually appear in late April or early May.

Other species of leafhoppers that attack legumes and vegetable crops in the western states are *Empoasca abrupta* DeL., *E. arida* DeL., *E. solana* DeL., and *E. filamenta* DeL. These species closely resemble *E. fabae* in general appearance and in the life cycle.

Clover Leafhopper, *Aceratagallia sanguinolenta* (Prov.) is generally dis-

tributed throughout North America. Although clovers are the common host it also attacks alfalfa, beans, cowpeas, other leguminous plants, and occasionally grasses.

The adult is about $\frac{1}{8}$ inch in length, robust with dark mottling (see Fig. 8). In the Northern States overwintering occurs in the adult stage under plant remnants in the field; in the extreme South and Southwest the leafhopper is active throughout the year. The adult female places her eggs in leaves and stems, these hatching in five to twelve days during the summer months in the latitude of southern Illinois. The nymphs pass through five molts and become adults in twenty-five or more days depending on the latitude. There are three generations annually in southern Missouri and more in subtropical areas.

Many predaceous insects, spiders, mites, birds, and parasitic insects attack leafhoppers, but none of these is abundant enough to give satisfactory control.

Cultural control measures for legumes are of value and can be accomplished by delaying the harvesting of the first crop about ten days. By that time many eggs are laid and will be removed from the field with the hay. Many tiny nymphs from hatched eggs also starve to death from lack of food.

Insecticides are the most effective method of preventing leafhopper damage to legumes. To determine the need for chemical treatment take a standard insect net and make twenty sweeps in each of five different parts of the field. Capturing an average of one or more potato leafhoppers per sweep is enough to justify insecticide application on alfalfa. Recommended chemicals are diazinon, malathion, and methoxychlor. Application should be made to the second or third cutting of alfalfa when the new growth is about 5 inches tall, or earlier if potato leafhopper is abundant. Allow seven days to elapse following treatment before feeding forage to livestock.

References: *J. Agr. Res.*, 43:267–285, 1931; *U.S.D.A. Tech. Bul.* 231, 1933; 850, 1943; *Farmers' Bul.* 737, 1916; *Leaflet* 521, 1963; *J. Econ. Ent.*, 50:493–497, 1957; 55:828–830, 973–978, 1962.

PLANT BUGS

Order Hemiptera, Family Miridae

Several species of plant bugs attack alfalfa, clover, cotton, sugar beets, many garden vegetable crops, and weeds. Damage on legumes is primarily to the flower buds and the developing seeds and it is caused by the piercing-sucking nymphs and adults. Effects produced are distorted growing tips and buds, flower fall, and phytotoxic reactions attributed to the salivary juices injected into the plant. These insects also cause oviposition injury

to the plant stems. The end result of all this damage is lowered seed and hay yields.

Alfalfa Plant Bug, *Adelphocoris lineolatus* (Goeze), was first reported in North America from Nova Scotia in 1917. The first record of its occurrence in the United States was from Iowa in 1929.

Since then it has spread gradually through the midwest, north central and North Atlantic states. Its common hosts are alfalfa and sweet clover.

Overwintering eggs in the stems of the host plants begin hatching in May, and the tiny green nymphs with red eyes pass through five instars in approximately thirty days, then transform to adults. These adults are light green tinged with brown and about $\frac{3}{8}$ inch long. In two weeks they begin egg-laying that results in a second generation by late August or early September. Only two generations occur in the latitude of St. Paul, Minnesota, and these overlap considerably.

Tarnished Plant Bug, *Lygus lineolaris* (P. deB.), is widely distributed in the United States and Canada, and feeds on many hosts, alfalfa, clover, cotton, sugar beets, and garden crops being the most common. Related species are *L. hesperus* Knight and *L. elisus* V. D., which are most abundant in the western and southwestern states where damage to alfalfa seed production is serious, especially from *L. hesperus*.

These bugs are scarcely $\frac{1}{4}$ inch in length, brown or tan and sometimes greenish, with darker markings (Fig. 215). They overwinter as adults,

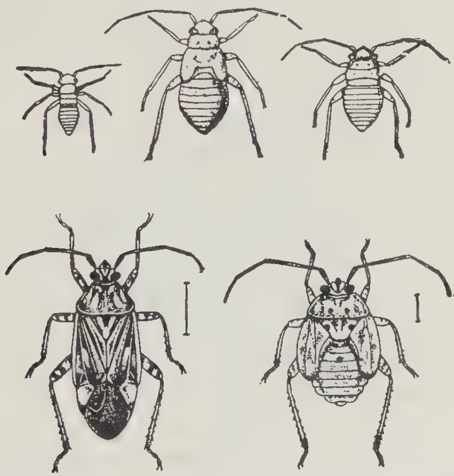


Fig. 215. Nymphs and adult of the tarnished plant bug, *Lygus lineolaris* (P. de B.). (U.S.D.A.)

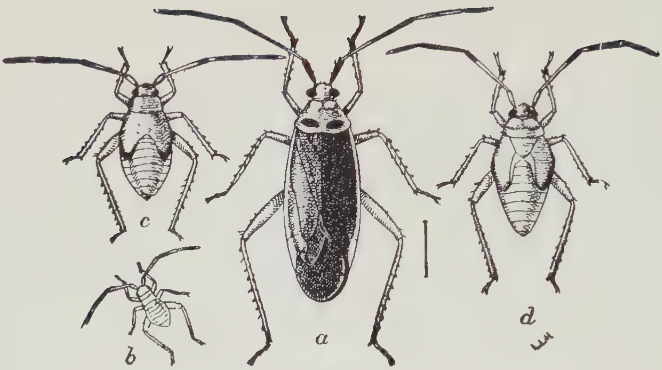


Fig. 216. The rapid plant bug, *Adelphocoris rapidus* (Say); *a*, adult; *b*, *c*, *d*, stages in growth of nymph. (U.S.D.A.)

becoming active in the spring and depositing eggs in the stems, petioles, and midribs of the hosts. Hatching occurs in about seven days and the greenish nymphs molt five times, reaching the adult stage in approximately thirty days. There are three to five generations annually depending on the latitude.

Rapid Plant Bug, *Adelphocoris rapidus* (Say), occurs in the United States and Canada primarily east of the 110th meridian where it feeds on many plants including alfalfa and sweet clover. The size, shape, habits and life cycle are the same as those of the alfalfa plant bug. In coloration the adult rapid plant bug is dark brown with yellow costal margins and a yellowish pronotum having two black spots near the base. The nymphs are red-tinged (Fig. 216).

In California, strip cutting of alfalfa shows promise as a cultural control measure for lygus bugs.

Chemical control of plant bugs on legumes is usually recommended only for seed crops. Chemicals to apply before bloom are chlordane, diazinon, or toxaphene. After bloom begins, California entomologists suggest dimethoate, toxaphene plus malathion or Dylox, DDT, or malathion, especially if resistance is a problem. This application is made in the early (10%) bloom period when 1 or more bugs are captured per sweep of an insect net (nymphs count as two). A second treatment is needed when the population reaches twelve bugs per sweep. In maturing fields, treatment is justified when twenty bugs are captured per sweep. Make applications after dark or in early morning before bees are foraging in fields. Crop remnants and residues must not be fed to livestock. Carbaryl is a chemical recommended for application to beans being attacked by plant bugs.

References: *U.S.D.A. Tech. Bul.* 741, 1940; *Minn. Agr. Exp. Sta. Tech. Bul.* 161, 1943; *Can. Dept. Agr. Pub.* 949, 1959; *Calif. Agr.*, 18 (4):4–6, 1964; *Agr. Exp. Sta. Leaflet* 86, 1964; *J. Econ. Ent.*, 56:532–533; 823–825, 1963; 57:225–230, 1964.

STINK BUGS

Order Hemiptera, Family Pentatomidae

Stink bugs are important pests of alfalfa grown for seed in south-western United States. Besides alfalfa, they also attack barley, wheat, oats, seed beets, okra, cotton, grain sorghum, squash, beans, peas, corn, cowpeas, tomatoes, vetch, and many weeds. Damage is caused by the nymphs and adults sucking sap, primarily from the pods, buds, blossoms, and seeds. Removing the liquid contents of the developing seeds causes them to become flattened and shrivelled.

Most stink bugs overwinter as adults in sheltered places such as fence rows, roadsides, ditch banks or other places where plant remnants are abundant. In early spring when temperatures reach 70° F. or above, they become active and begin egg-laying. A female may deposit three hundred to five hundred eggs in clusters, each containing an average of thirty, over a period of a month or more. Hatching occurs in approximately a week and after five nymphal instars the adult stage is reached in almost six weeks, depending on the species and the prevailing temperatures. Repeat generations occur at five- to six-week intervals during the summer. Adults usually live forty to sixty days in spring and summer, but overwintering individuals may live seven to nine months.

Say Stink Bug, *Chlorochroa sayi* Stål, is a widely distributed species

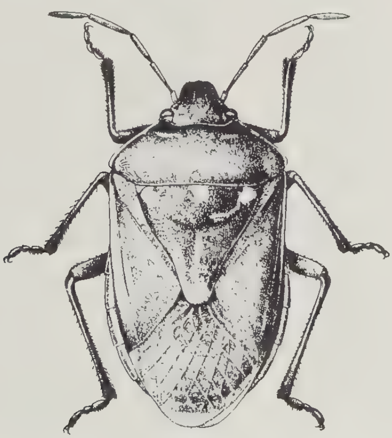


Fig. 217. Say stink bug, *Chlorochroa sayi* Stål. (Caffrey and Barber, U.S.D.A.)

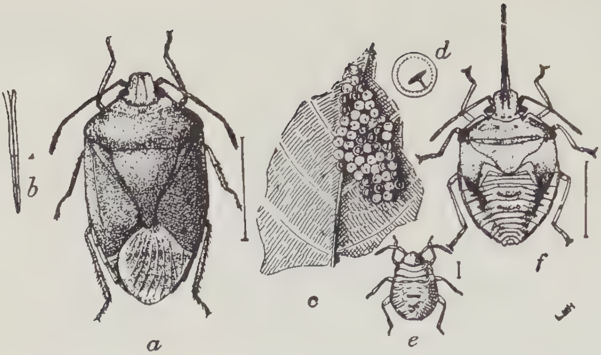


Fig. 218. The green stink bug, *Acrosternum hilare* (Say), an occasional pest of cotton: *a,* adult; *b,* beak; *c,* eggs; *d,* end of egg more enlarged; *e,* young nymph; *f,* last stage of nymph. (U.S.D.A.)

in the western states, from Mexico to Canada. It is the most destructive species on seed alfalfa in Arizona. Adults vary in color from dark green in the spring to light green in midsummer, and to olive or red-brown in the fall and winter. The most characteristic markings are three large pale spots on the anterior margin of the scutellum (Fig. 217).

Western Brown Stink Bug, *Euschistus impictiventris* (Stål), occurs mainly in Mexico, Texas, New Mexico, Arizona, Colorado, Utah, Nevada, and southern California. This species was second in abundance on seed alfalfa in Arizona. Adults are slightly smaller than the Say stink bug, uniformly yellowish brown with the lateral angles of the pronotum prominent and sharply pointed.

Green Stink Bug, *Acrosternum hilare* (Say), is a large green species (Fig. 218), widely distributed in North and Central America but more injurious in the South than in the North. It attacks many wild and cultivated plants, including alfalfa, lima beans (Fig. 219), peaches, and cotton.

Southern Green Stink Bug, *Nezara viridula* (L.), is quite similar in appearance to *A. hilare* but slightly larger. It is found primarily in the southeastern states and Gulf Coast regions. Host plants are many including legumes, vegetable crops, and citrus fruits.

Red-Shouldered Stink Bug, *Thyanta pallido-virens spinosa* Ruckes, is generally distributed in the southwestern states. A closely related species, *T. custator* (Fabricius), is common along the Atlantic and Gulf Coast states. These are the smallest species included in this discussion. Adults are of variable shades of green with red-brown antennae. Very few of the southwestern species have the red-shoulders. On some specimens a narrow reddish band joins the lateral angles of the pronotum and the margins; medial

line and apex of the scutellum frequently have light yellow or red markings.

Conchuella Stink Bug, *Chlorochroa ligata* (Say), has been reported mainly from Mexico, Arizona, Texas, New Mexico, Colorado, Utah, and California. The color varies from dull olive or ash gray to a green, purplish pink, or reddish brown. The most characteristic markings are an orange-red band along the lateral margins of the thorax and the costal margins of the wings and a spot of the same color on the tip of the scutellum.

Control measures consist of destroying hibernating quarters where practical; controlling weeds late in winter and in spring, in and surrounding the crop subject to attack; growing seed alfalfa as far removed as practical from sugar beets or small grains; planting and harvesting legume seed crops on uniform dates in all fields in a community or area; growing seed crops as rapidly as good agronomic practices permit; and using proper insecticides.

Chemicals that give control of stink bugs are DDT, parathion, methyl parathion, toxaphene, Strobane, carbaryl, guthion, endosulfan, trichlorfon, and combinations of DDT plus methyl parathion, and Strobane plus toxaphene. Selection of the proper chemical will depend on the crop to be protected. On legumes applications should be made before blooming to avoid killing pollinating insects. Secure recommendations prepared for your area by the agricultural extension service.

Fig. 219. Damage to beans by green stink bugs: (left) *Nezara viridula* (L.); (right) *Acrosternum hilare* (Say). (U.S.D.A.)

References: *Arizona Agr. Exp. Sta. Tech. Bul.* 140, 1960; *Bul.* A-23, 1962; *J. Kans. Ent. Soc.*, 34:151–157, 1961; *U.S.D.A. Cir.* 903, 1952; *J. Econ. Ent.*, 45:254–257, 1952; 57:60–62, 1964.

MISCELLANEOUS LEGUME PESTS

Alfalfa Snout Beetle, *Brachyrhinus ligustici* (L.), is of central European origin and was first recorded in the vicinity of Oswego, N.Y., in 1933. However, checking of collections revealed specimens from that locality dated 1896. The known distribution is still confined to the region where the discovery of its presence was first made. Damage is caused by the larvae feeding on the roots and the adults feeding on the foliage of alfalfa, other legumes, and a great variety of plants.

All the beetles are females and reproduction is therefore parthenogenetic. These flightless adults are nearly $\frac{1}{2}$ inch in length, each having a large prominent snout (Fig. 220). Larvae are white and curved, resembling others in the family Curculionidae. The life cycle requires two years, perhaps three under unfavorable conditions. Hibernation occurs in the adult and half-grown larval stages.

Suggested control measures are short rotations with row crops, planting red clover in place of alfalfa, and poisoned baits containing 4 oz. of aldrin, dieldrin, or heptachlor, or 8 pounds of sodium fluosilicate for killing adults in freshly plowed infested sod. Select one of these toxicants and mix it with 85 pounds of peanut shells, 20 pounds of sugar, 18 pounds of soybean flour, and 12 gallons of water. Apply, after mixing, at the rate of approximately 3 bushels of bait per acre.

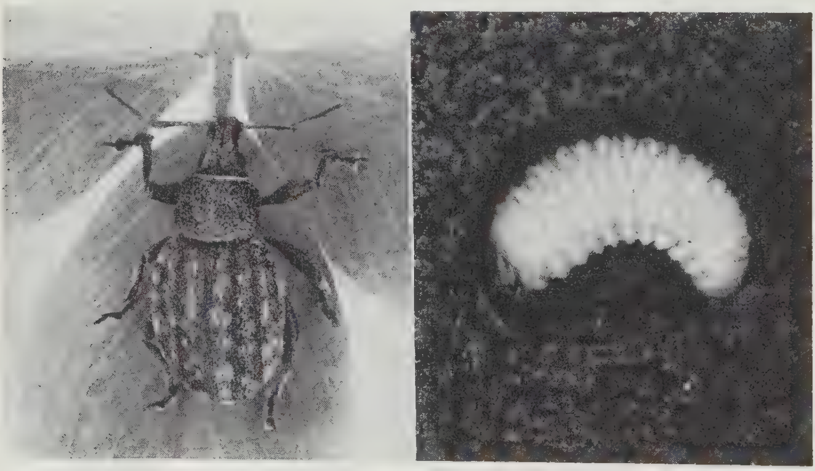


Fig. 220. The alfalfa snout beetle, *Brachyrhinus ligustici* (L.); adult and larva. (Palm, Cornell Agr. Exp. Sta.)

References: *Cornell Bul.* 629, 1935; 757, 1941; *J. Econ. Ent.*, 30:715, 1937; 45:298–302, 1952; 51:682–685, 1958; 54:601, 1961.

Alfalfa Caterpillar, *Colias eurytheme* Boisduval, is a green caterpillar covered with a fine pubescence, and approximately 1 inch long when fully developed (Fig. 221). It is the larva of one of the medium-sized yellow butterflies with black-bordered wings, common over the greater part of the country. Over much of its range this chewing caterpillar is of little consequence but in the southwestern states, especially in irrigated sections, it sometimes becomes so numerous as to destroy much alfalfa.

Fig. 221. The alfalfa caterpillar, *Colias eurytheme* Boisduval. (U.S.D.A.)

In the Southwest all stages may overwinter and there may be seven generations per year, whereas in the North only pupae overwinter and the number of generations is less, depending on the latitude.

A virus disease causing what is known as "caterpillar wilt" is perhaps the best controlling agent. The organisms causing this disease occur naturally in the soil, stubble, and crop remnants in fields, especially where alfalfa is grown. Both larvae and pupae are destroyed in great numbers. The California Agricultural Experiment Station has shown that a suspension of this virus applied as a spray to infested alfalfa, gives more immediate control than dependence on the natural spread of the virus. If 15% of the caterpillars are killed by this disease when the plants are about one-third grown, insecticides may not be needed.

A braconid, *Apanteles medicaginis* Mues., and a tachinid fly, *Euphorocera claripennis* (Macquart), are important parasites that destroy great numbers of caterpillars, especially later summer generations.

Cutting an infested crop early, close, and clean will remove food and shelter for the caterpillars and butterflies, reducing their numbers. Flooding the closely mowed field after removal of the hay also contributes to control. To determine the need for chemical control measures, sweep the plants in different parts of the field with an insect net 15 inches in diameter. If ten or more normal caterpillars are collected per sweep in an

average stand, insecticides should be applied promptly. Commonly recommended materials are methoxychlor, DDT, Dylox, mevinphos, and *Bacillus thuringiensis* Berliner. DDT should be applied only to seed crops.

References: *U.S.D.A. Leaflet* 325, 1963; *Calif. Agr. Exp. Sta. Leaflets* 85 and 86, 1964.

Green Cloverworm, *Plathypena scabra* (F.), is universally distributed from the Mississippi Valley eastward, extending down from Canada to the Gulf. Damage is caused by the caterpillars devouring the leaves of clover, alfalfa, soybeans, cowpeas, and other leguminous plants. The slender green worms with faint white stripes may attain a length of an inch or more when fully grown (Fig. 222). Adults are dark brown, almost

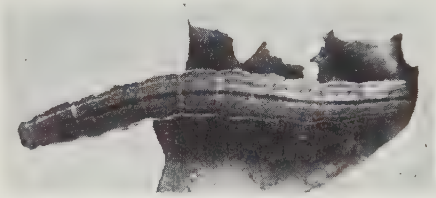


Fig. 222. The green cloverworm bearing egg of a parasitic fly. (U.S.D.A.)

Fig. 223. Adult of the green cloverworm, *Plathypena scabra* (F.). (Hill, U.S.D.A.)

black, with lighter markings, and a wingspread of nearly $1\frac{1}{4}$ inches (Fig. 223).

Winter is passed in the pupal or adult stage. Activity begins in the spring with the coming of warm weather, the eggs being deposited singly on the host plants. Larval development requires nearly a month and the pupal period from two to three weeks, this stage being passed in a silken cocoon in the litter on the ground. There are three to four generations in the South and two in the North. Control measures are seldom necessary. If an outbreak justifies the application of chemicals, carbaryl, toxaphene,

or methoxychlor are suggested. Use them at the rate of 1 to 1.5 pounds per acre.

Alfalfa Webworm, *Loxostege commixtalis* (Walker), is the larva of a small moth not unlike the garden webworm pictured elsewhere in this book (p. 313), and it has some resemblance to the corn borer. The larva is a slender, greenish yellow, striped caterpillar, which reaches a length of about 1 inch. Pupation takes place in the soil with three generations occurring in the latitude of Colorado. There are many hosts in addition to alfalfa. When the food supply is nearly exhausted this species will sometimes migrate like the armyworm.

Harvesting infested crops for hay will greatly check this insect. Chemicals giving good control are Dylox and toxaphene at 4 ounces and $1\frac{1}{2}$ pounds per acre respectively. Dylox is less hazardous and is the preferred chemical.

Garden Webworm, *Loxostege similalis* (Guenée), and the **Beet Webworm,** *Loxostege sticticalis* (L.), both damage alfalfa as well as their usual hosts in seasons when they are unusually abundant. Their larvae devour the leaves and stems and spin silken threads resulting in objectionable webbing on hay crops. The control measures are the same as those given for the alfalfa webworm.

References: *U.S.D.A. Agr. Handbook* 313, 1966; *J. Econ. Ent.,* 56:248–251, 1963; *Calif. Agr. Exp. Sta. Leaflet* 85, 1964.

Alfalfa Looper, *Autographa californica* (Speyer), is the larva of a noctuid moth. On several occasions this insect has done extensive damage in western Canada and the Pacific coastal states. The looping larva devours the leaves of alfalfa, lettuce, and other crops. On edible crops where residues would be a hazard, use dusts containing 1.0% rotenone or 0.1% pyrethrins. The recommended chemicals for sugar beets are parathion and Dylox. For blackeye peas use methoxychlor or malathion plus Perthane. In California, natural control by insect parasites, bacterial and fungus diseases has made the application of chemicals unnecessary.

Reference: *J. Econ. Ent.,* 46:723, 1953.

Forage Looper, *Caenurgina erechtea* (Cramer), is considered a minor pest of clover and alfalfa in the plains region of Kansas and surrounding states. Overwintering occurs as a pupa enclosed in a cocoon in the soil near the base of the food plants. Moths appear early and deposit eggs which hatch into looping caterpillars; the latter devour the new growth of the hosts (Fig. 224). There may be three or four generations per year in Kansas, and the damage done by the later generations is the most serious. Heavy parasitism of the larvae normally keeps the pest under control.

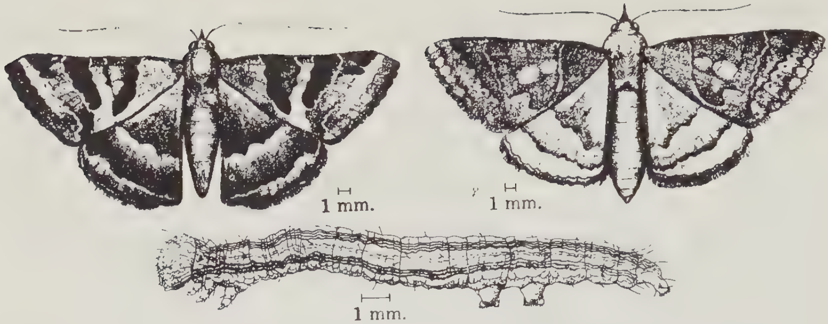


Fig. 224. The forage looper, *Caenurgina erechtea* (Cramer); male and female adults and young larva. (Prince, Kansas Agr. Exp. Sta.)

When chemical control is needed, the insecticides recommended for armyworms and cutworms are suggested (p. 147). Selection of the appropriate chemical will depend on the crop to be protected.

Reference: Kansas Bd. of Agr., *29th Ann. Rep.*, 1935.

Clover Head Caterpillar, *Grapholitha interstinctana* (Clemens), is a rather local and occasional pest, mainly on red clover. It is more abundant in the northeastern states and southern Canada. Damage is caused by the larvae feeding on the leaves near the crown and also in the developing clover heads. Overwintering occurs in the larval and pupal stages under crop residues in or near clover plantings. In the spring these larvae pupate and adult moths begin emerging from them as well as from the overwintering pupae, about the time red clover is beginning to bloom. The moths are nearly $\frac{1}{4}$ inch in length, dark brown with white markings on the costal margins of the wings, and light dorsal spots forming a double crescent when the wings are folded. Eggs are laid on the leaves, stems, and heads, and upon hatching the larvae feed for a period of almost five weeks, then spin cocoons on the ground and change to pupae. After two weeks elapse the new adults begin emerging and soon afterwards lay eggs which form the second generation. A third generation may develop in more southern latitudes.

Harvesting the first crop while the worms are still partially developed usually prevents damage to the later crop grown for seed. There are several parasites known; since little mention has been made of this insect recently, it would seem that they must be rather effective in control.

Clover Seed Midge, *Dasineura leguminicola* (Lintner), is widely distributed in the United States and southern Canada. Red clover is the common host it attacks in injurious numbers. The midge passes the winter as a

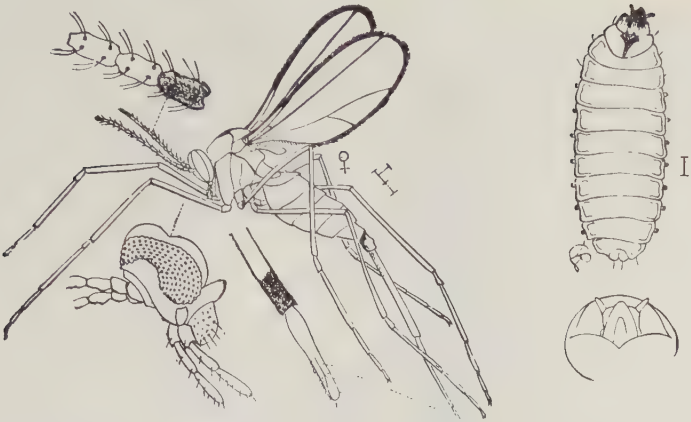


Fig. 225. The clover seed midge, *Dasineura leguminicola* (Lintner). (Riley.)

larva in the soil. Pupation occurs in early spring and the tiny mosquito-like adults (Fig. 225) emerge soon afterwards, laying their light yellow eggs in the young clover heads. In a few days hatching occurs and the yellow larvae feed, causing imperfect heads and preventing formation of seed. These heads often fall to the ground and when the larvae in them have become fully grown they pupate in the soil and soon produce a second generation. Sometimes a third generation is produced in more southern areas of the country. If infested clover is cut before it comes into full bloom and is then removed from the field when cured, the young midge larvae are killed. To be effective this operation must be carried out before the larvae are fully developed. Pasturing red clover previous to starting a seed crop has given good control in the more northern latitudes. If neither pasture nor a hay crop is desired, clipping the field about May 20, leaving the clippings on the ground, will delay the production of heads until after the adults of the spring generation are gone. These heads will be advanced enough in development for seed production to be immune from attack by adults of the summer generation.

References: *U.S.D.A. Farmers' Bul.* 971, 1947; *Leaflet* 379, 1954.

Clover Stem Borer, *Languria mozardi* Latr., is a minor pest of red clover and alfalfa but has been found feeding on other clovers and a number of weeds. It is widely distributed throughout North America. The beetle is elongated, nearly $\frac{3}{8}$ inch in length, with a red head and thorax and blue-black elytra (Fig. 226). The pale yellow larva is very slender and tunnels in the stems of the hosts with pupation occurring in the same burrows. The average time required for the life cycle is about fifty days. There is a single generation in the East, but there may

Fig. 226. The clover stem borer, *Languria mozardi* Latr.; adult and larva. (Wildermuth and Gates, U.S.D.A.)

be three in the Southwest where the early broods develop in wild sweet clover. Overwintering occurs in the adult stage.

Several parasites attack this insect but the chalcid wasp, *Habrocytus languriae* Ashmead, is said to be the most important. Destruction of host plants or cutting infested hay crops before the larvae mature reduces the population, along with rotating crops and continual pasturing. Chemicals that control other legume insects will undoubtedly check this pest if necessary.

Reference: *U.S.D.A. Bul.* 889, 1920.

Blister Beetles of several species attack clover, alfalfa, and related plants, often causing extensive damage but only in the adult stage. The larval stages occur in the soil where they feed on the eggs of grasshoppers and are therefore beneficial. Early harvesting may avert considerable loss in forage crops since the adults appear later in the summer. Where chemical control measures are justified, apply either methoxychlor, DDT, carbaryl, or parathion. Possible hazards from poisonous residues should be considered when choosing the insecticide.

Three-Cornered Alfalfa Hopper, *Spissistilus festinus* (Say), is a treehopper which injures alfalfa, beans, cowpeas, tomatoes, melons, cotton, and other plants by puncturing the stems in sucking sap and in ovipositing. These punctures may be arranged in such a manner as to girdle

the stem. The treehopper is injurious in the southern states but may be found north to the Canadian border. So far the insect has been only local in its importance and cultural measures have been proposed for its control. These include the destruction of weed patches and other vegetation that serve as food and shelter from which the hoppers may migrate to crop plants. Carbaryl, DDT, toxaphene, and parathion are suggested insecticides should chemical control become necessary. A more convenient name sometimes used for this insect is alfalfa treehopper.

References: *J. Agr. Res.*, 3:343–362, 1915; *J. Econ. Ent.*, 42:694, 1949; 52:428–432, 1959.

Lima Bean Pod Borer, *Etiella zinckenella* (Treit.), is, at times, a serious pest of lima beans and lupines in California. Damage is caused by the caterpillars (Fig. 227) boring into the pods and devouring the developing seeds. Using carbaryl at 2 pounds per acre as the pods are forming followed by repeat applications at ten day intervals is the recommended control measure.

Reference: *U.S.D.A. Tech. Bul.* 1321, 1965.

Fig. 227. The lima bean pod borer, *Etiella zinckenella* (Treit.). (U.S.D.A.)

Fig. 228. The leaf-footed bug, *Leptoglossus phyllopus* (L.). (U.S.D.A.)

Lima Bean Vine Borer, *Monoptilota pergratialis* (Hulst), has been found in Maryland and other southern states where it sometimes injures lima beans by boring into the vines. Two generations are known in Maryland where the winter is spent in the soil as a pupa. Winter cultivation is suggested as a means of control.

Leaf-Footed Bug, *Leptoglossus phyllopus* (L.), has the appearance shown in Fig. 228. By means of its piercing-sucking mouthparts, plant sap is

removed from the leaves and pods of beans, cowpeas, velvetbeans, other legumes, and occasionally grain sorghum. It attracts attention by its large size and striking color as much as by the damage it causes. If chemical control is necessary apply carbaryl or DDT.

VELVETBEAN CATERPILLAR

Anticarsia gemmatalis (Hübner), Family Noctuidae

The velvetbean caterpillar is frequently a serious pest of soybeans, velvetbeans, cowpeas, peanuts, alfalfa, and related plants. It is the larva of a small noctuid moth, a tropical species found only in the Gulf states. Rarely does it survive the winter in continental United States except in the southern tip of Florida. However, it migrates northward each year and has been found as far as Delaware in late September. Adults usually appear in June or July and deposit tiny, round, white eggs on the undersides of the leaves of the host. These hatch in four days into slender green caterpillars with faint stripes, that feed for about three weeks, then pupate less than 2 inches below the surface of the soil. Adults emerge approximately ten days later, completing the cycle. As many as three generations occur per season and the most serious damage occurs in early autumn.

Control can be accomplished by applying carbaryl, DDT, methoxychlor, methyl parathion, mevinphos, or toxaphene. Applications should be made when the young caterpillars are hatching from the eggs. The poisonous characteristics of the insecticide should be considered if the crop remains are to be fed to livestock.

References: *J. Econ. Ent.*, 41:803, 1948; *U.S.D.A. Leaflet* 348, 1959.

PEA APHID

Acyrthosiphon pisum (Harris), Family Aphididae

The pea aphid, assumed to be of European or Asiatic origin, was first recorded in this country in 1879. Distribution is general throughout the United States and southern Canada where the host plants are grown. It attacks all kinds of peas, alfalfa, clover, and other leguminous crops. The resulting loss to the pea grower probably exceeds that caused by any other pest of the crop and the losses from forage crop attacks are often of considerable importance.

The pea aphid pierces the leaves, stems, blossoms, and pods of the plant and sucks the sap. This causes stunting of all parts, resulting in fewer and smaller pods, which are often only partly filled with peas. Pea aphid feeding causes some plants to wilt and turn yellow.

This aphid also transmits the causal organism of several virus diseases of pea plants. The diseases occur more frequently in the Pacific Northwest than in other sections of the country. One of the most important

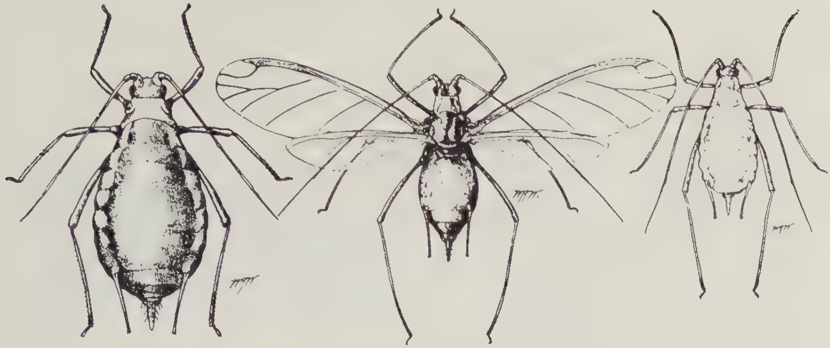


Fig. 229. The pea aphid, *Acyrthosiphon pisum* (Harris); adult stem mother, winged ovoviviparous female and wingless ovoviviparous female. (U.S.D.A.)

diseases is yellow bean mosaic, which is widespread in alfalfa. Another virus disease, known as enation mosaic, may appear late in the season. Infected pods become tough and difficult to shell, and the quality of the peas is lowered.

The adult aphid is nearly $\frac{3}{16}$ inch long and $\frac{1}{3}$ as wide; it is light to deep green in color, has red eyes and its legs and cornicles are usually tipped with yellow. Except for size, the young nymphs look like the adults (Fig. 229).

In the warmer areas this aphid remains active most of the winter and continues to reproduce with the egg stage entirely lacking. In cooler regions the winter eggs are laid on alfalfa and clover and the early generations of the following year are present only on these plants. In April or May, depending on the latitude, the eggs hatch into wingless parthenogenetic females which, after reaching the adult stage, give birth to young nymphs, often ten to fourteen per day. Winged aphids appear at the second or third generation and fly to pea fields and other leguminous plants, often producing, under favorable conditions, twelve or more wingless generations in rapid succession throughout the summer. As peas and other hosts approach maturity and become less favorable for feeding, winged adults again appear. Many of these fly back to alfalfa and clover where males and egg-laying females are produced. The shining black eggs are deposited on the stems and leaves of alfalfa and clover, becoming the overwintering stage in the northern range of this insect.

Many natural controls often operate to keep the insect population below the point where commercial injury may result. There are 76 known parasites and predatory enemies of this aphid. The groups, in the order of their importance, are syrphid flies, lady beetles, fungus diseases, braconid parasites, and aphid lions or lacewings. A preponderance of predators

appears in the list; some beneficial forms themselves are hosts or prey to other parasites or predators.

Research in Wisconsin has shown that the varieties Pride, Yellow Admiral, and Onward were somewhat resistant to pea aphid attack.

Effective chemical control measures are now widely practiced and commonly applied as sprays or dusts by ground equipment or aircraft. Insecticides applied when the infestations are light give best control. A suggested method of determining the infestation is to make a half-circle sweep with a collecting net 15 inches in diameter and a handle 3 feet long. If thirty to forty aphids are obtained in one sweep it is advisable to treat at once. Any one of the following chemicals will control pea aphids: demeton, diazinon, malathion, mevinphos, naled, parathion, TEPP, and Di-Syston. Exercise all precautions in handling these highly toxic compounds.

References: *U.S.D.A. Bul.* 276, 1915; *Tech. Bul.* 1287, 1963; *Leaflet* 529, 1964; *Farmers' Bul.* 1945, 1952; *Maine Bul.* 337, 1927; *J. Econ. Ent.*, 56:205–213, 1963; *Calif. Agr. Exp. Sta. Leaflet* 85, 1964.

PEA MOTH

Laspeyresia nigricana (Stephens), Family Olethreutidae

A native of Europe, the pea moth was introduced into Canada about 1893. Since then it has become established in several northern states bordering Canada and some of the provinces of that country. It is sometimes considered an important pest.

The brown moths with a wingspread of $\frac{1}{2}$ inch begin emerging from overwintering cocoons in July and are active until sometime in August; during this period the white flattened eggs are laid. Eggs may be placed on any part of the plant and, on hatching, the larvae bore into the pods. They feed on the developing seeds (Fig. 230) and spin a light web in the process. Several larvae may infest a single pod. Fungus growth often follows their work and spoils seeds that are undamaged by the worms. Larval development is completed in three or more weeks, after which they bore out of the pods, enter the soil and spin cocoons. A few of these larvae pupate and adults emerge to form a partial second generation, but most of them overwinter and pupate in late spring of the following year.

Control measures suggested are early planting and the selection of early-maturing varieties to produce the crop before the adults are present in the field. Rotation of crops and deep and clean plowing of infested fields in the fall or early spring are also of value in eliminating this pest.

References: *Mich. Quart. Bul.* 14:87, 1931; *Wash. Agr. Exp. Sta. Bul.* 327, 1936; *Mich. Ext. Bul.* 312, 1952; *Wis. Agr. Exp. Sta. Bul.* 310, 1920.

Fig. 230. The pea moth, *Laspeyresia nigricana* (Stephens), and typical infested peas.

PEA WEEVIL

Bruchus pisorum (L.), Family Bruchidae

So far as is known the pea weevil is a native of North America. It is widely distributed and attacks all varieties of edible and field peas whether grown for processing or for seed. Damage done by the larva is restricted to the seed which it first enters shortly after hatching. In the course of development the growing larva consumes the central portion of the pea, lowering or destroying the viability of the seed as well as rendering it unfit for human consumption and destroying its value for stock feed.

The adult insect is about $\frac{1}{5}$ inch in length, dark brown or black, with light pubescence arranged in a characteristic pattern (Fig. 231). The white larva is thick-bodied, curved, and almost legless.

Adult beetles hibernate in a great variety of protected places but commonly in field crop remnants, stored peas, or pea hay. With the coming

Fig. 231. The pea weevil, *Bruchus pisorum* (L.): *a*, adult; *b*, larva; *c*, pupa. (Chittenden, U.S.D.A.)

of warm weather, they emerge and are attracted to the blooming peas upon which they feed and lay eggs. The orange oval eggs are cemented to the pods by a secretion. Hatching usually occurs in a week and the tiny larvae eat through the pod and enter the peas where development is completed at the end of about six weeks. Pupation takes place within the hollowed seed and after a period of a week or more the new adults emerge, completing the cycle, which averages about two months in the northwestern states. There is only one generation per year.

The principal source of pea weevil infestation are peas shattered in the field, volunteer peas, pea hay containing weevil-infested peas, and weevil-infested seeds in storage. Any sanitation, mechanical, cultural, or chemical control measures limiting further development are of value in eliminating this pest. Fumigation or other treatment of the seed to kill the weevils is a very important practice in the control program (p. 573). Where infestation is heavy, even the greatest care in promoting these practices will not insure freedom from infestation, so that field treatment with insecticides is imperative.

Field infestations may be controlled with dusts containing 0.75% rotenone, 5% DDT or methoxychlor applied during the early bloom period before the eggs are laid. From one to three applications should be made at the rate of twenty to thirty pounds per acre. Use only rotenone or methoxychlor if the pea hay or ensilage is to be fed to livestock. For dry peas, usually one well-timed application of 5% DDT dust will be sufficient. If pea aphids are also a problem, apply malathion or parathion, as recommended for that insect (p. 274).

To determine the need for treatment use an insect net and sweep the upper part of the vines soon after the first blossoms appear. A population of five weevils in fifty sweeps results in an infestation at the canning stage of 1 to 2% in early varieties and 15 to 20% in later varieties. An infestation of 3 to 8% in harvested dry peas results from finding one weevil in twenty-five sweeps at blooming time.

References: *U.S.D.A. Tech. Bul.* 599, 1938; *Farmers' Bul.* 1971, 1952.

BEAN WEEVIL

Acanthoscelides obtectus (Say), Family Bruchidae

Although the bean weevil is well known in the North where it is a pest of stored beans only, in the South and Southwest it is a serious pest in the field as well as in storage. Once commonly considered native to this country, it is now thought to have been imported from Central or South America. It is widely distributed over the world. Food plants of importance are the different varieties of common beans, *Phaseolus vulgaris*

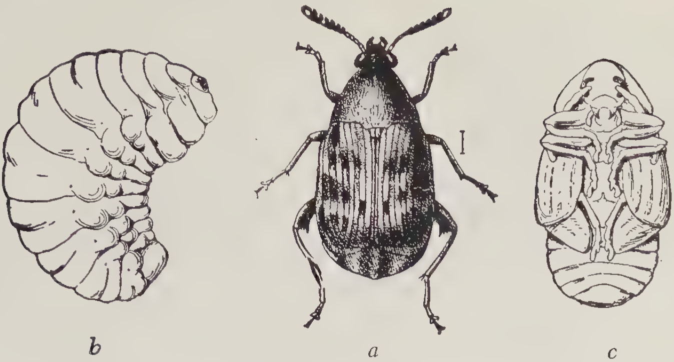


Fig. 232. The bean weevil, *Acanthoscelides obtectus* (Say): *a*, beetle; *b*, larva; *c*, pupa; all greatly enlarged. (U.S.D.A.)

L., and cowpeas, *Vigna sinensis* (L.). The weevils have been bred from many other kinds of garden beans and peas, as well as from seeds of plants in other groups. Damage consists of complete or partial destruction of the infested seeds. Under heavy infestations as many as a dozen or more weevils may develop from a single seed.

Adult bean weevils are $\frac{1}{10}$ to $\frac{1}{8}$ inch in length, brownish black in color with lighter spots on the elytra (Fig. 232). The larvae are thick-bodied, curved, white, and footless except in the first instar. Larvae and pupae are found only in the seeds within which all development occurs. White oval eggs are laid on beans in storage and on or in pods in the field. Over two hundred eggs have been recorded from one female. Hatching occurs in three to nine days, larval development through four instars requires twelve days to six months, and the pupal period, eight to twenty-five days. The prevailing temperatures greatly affect the speed of development, and frequently six or more generations are produced in a year. Usually only one or two of these are produced in the field, the others developing in stored beans.

Control of the bean weevil may be accomplished by thoroughly cleaning up and destroying all remnants of the crop after harvest. This may be done by plowing to bury all the vines and beans that have shattered. Storage places should be freed of weevils by sanitation and fumigation measures. All beans, whether for seed or food purposes, should be carefully inspected and, if any weevils are present, fumigated or given other treatments as recommended under control of stored product pests (p. 570). It is essential that all weevils in stored beans be eliminated in order to prevent field infestation in the spring or summer. Field infestations ordinarily result from weevils coming from infested stored seeds. If chemical

control in the field should become necessary, the insecticides recommended for pea weevil are suggested.

Reference: *U.S.D.A. Tech. Bul.* 593, 1938.

BROADBEAN WEEVIL

Bruchus rufimanus **Boheman, Family Bruchidae**

This weevil infests broad beans grown principally in California for human consumption or for stock feed. Damage is caused by the larva feeding and transforming to the adult within the beans. The insect resembles the pea weevil in habits and appearance, but it is smaller in size. Hibernating adults become active early in April and begin laying eggs on the newly developing pods. Approximately nineteen weeks later the new adults begin emerging from the beans. Some adults leave the beans as soon as development is completed but others may remain within the seeds in storage for a period of several months. There is but one generation per year.

Delayed planting, clean culture, sanitation and fumigation of infested seeds are suggested control measures. Although no statements to the effect have yet appeared, it seems entirely possible that all the insecticides recommended for controlling pea weevil should serve the same purpose for this insect. A 5% DDT dust applied just preceding oviposition has given the best control in tests with a few insecticides.

References: *U.S.D.A. Bul.* 807, 1920; *J. Econ. Ent.*, 44:240–243, 1951.

COWPEA WEEVIL

Callosobruchus maculatus **(Fabr.), Family Bruchidae**

This insect is a primary pest of cowpeas but may also attack beans and seeds of other related plants. Development from larvae to adults takes place entirely within the seeds. Weevily cowpeas and beans are unfit for human food and if badly infested are unsuitable for planting. The cowpea weevil was probably imported from some part of the original range of its preferred food plant, the Old World subtropical regions. It occurs in the southern states and California, and there are scattered records from some northern states where it is found only in stored seeds.

Adults are a trifle larger than those of the bean weevil but very similar in other characteristics, except for a large lateral black spot on each wing cover and the darker posterior margins (Fig. 233). The whitish oval eggs are cemented in or on maturing pods in the field or on dry seeds in storage. The white larvae pass through four instars within the seed, requiring fourteen days to nine months, depending on the temperature. Pupation and adult emergence follow, with six or seven generations produced in

Fig. 233. The cowpea weevil, *Callosobruchus maculatus* (Fabr.); adult, egg, larvae, and damaged seed. (Larson and Fisher, U.S.D.A.)

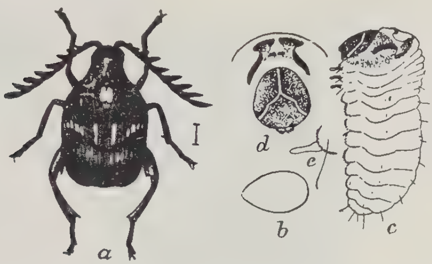


Fig. 234. The southern cowpea weevil, *Bruchidius chinensis* (Thunberg): *a*, adult male; *b*, egg; *c*, young larva; *d*, front view of larval head; *e*, leg of larva; all enlarged. (U.S.D.A.)

California and nine in Texas. In more northern localities, the number of generations is greatly reduced.

A closely related species is the southern cowpea weevil, *Bruchidius chinensis* (Thunberg), which attacks the same hosts and has a similar life cycle. It is smaller in size with two white spots on the posterior margin of the prothorax and a prominent dark spot on each wing cover. The males have pectinate antennae (Fig. 234).

Control of these insects can be accomplished by the same measures recommended for the bean weevil.

References: *Texas Bul.* 256, 1919; *U.S.D.A. Tech. Bul.* 593, 1938; *J. Econ. Ent.*, 56:588–591, 1963.

MEXICAN BEAN BEETLE

Epilachna varivestis Mulsant, Family Coccinellidae

This insect is one of the two plant-eating species of lady beetles. It is a native of the semiarid southwestern states, the original range having been in Mexico or in territory which once formed a part of that nation. In 1920 it was found in Birmingham, Alabama, and since that time has spread throughout the greater part of the United States east of the Mississippi River and bordering areas to the west as well. An infestation was found in California in 1946.

The Mexican bean beetle commonly attacks various varieties of bush, pole, and lima beans, the greatest damage usually occurring in the order named. Although it can reproduce on both cowpeas and soybeans, injury to soybeans is more common. It also attacks ladino clover and beggartick. The feeding by the larvae and adults, primarily on the lower surface of the leaves, results in skeletonized foliage.

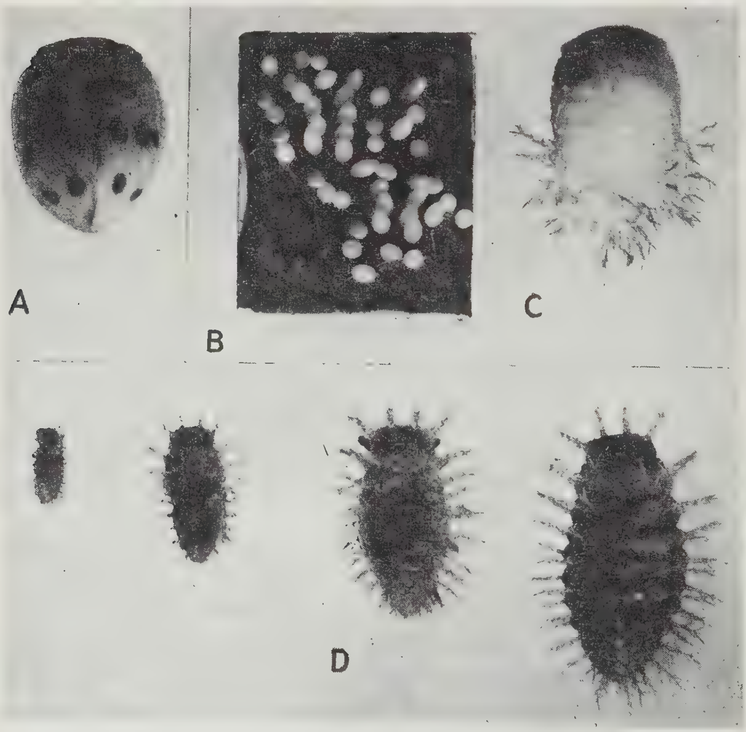


Fig. 235. Stages of the Mexican bean beetle, *Epilachna varivestis* Mulsant; *A*, adult; *B*, egg mass; *C*, pupa; *D*, four larval stages. All slightly over 4 times natural size. (U.S.D.A.)

The adult is yellow, coppery, or bronze, depending on its age, with sixteen black spots on the wing covers. It is hemispherical in shape and about $\frac{5}{16}$ inch long. The females deposit yellow eggs in masses of forty to sixty on the undersides of the leaves. Over 1500 eggs may be deposited by a single female, but the average is about 460. The newly hatched spiny larvae are green, gradually becoming yellow as they near the fully developed stage, then changing to the broad, yellow pupae that are attached to the plant by the gray-colored, last larval molt skin at the posterior end. All life stages are illustrated in Fig. 235.

Only the adult beetle overwinters, usually among plant remnants on the ground. The starting date of beetle activity in the spring is dependent on the prevailing temperature. In the North they are usually noticed in late May and early June, feeding on bean foliage. Egg-laying soon follows with hatching taking place in about seven days. There are four larval instars, each approximately five to seven days apart, followed by a pupal period lasting a week. The total developmental period from egg to adult averages about thirty-three days in midsummer; this is greatly extended in cooler weather. There are one to four generations per year, depending on the latitude.

Some natural control by parasitic flies, predaceous bugs, and lady beetles occurs, but it is never great enough to be of much value. Extremely hot dry summers and cold winters also limit populations.

Several insecticides are available that give control if applied as the eggs are hatching and if directed to the undersides of the leaves. They are rotenone, carbaryl, malathion, diazinon, methoxychlor, parathion, naled, trithion, and Di-Syston. Great care should be exercised in handling the insecticides that are highly toxic. Home gardeners should only use rotenone, carbaryl, methoxychlor, or malathion. Rotenone is the least hazardous from the standpoint of effects to the person applying it and the residues left on the plant.

Reference: *U.S.D.A. Farmers' Bul.* 1624, 1960.

BEAN LEAF BEETLE

Cerotoma trifurcata (Förster), Family Chrysomelidae

The bean leaf beetle is widely distributed in the United States and attacks beans, peas, cowpeas, soybeans, and several other plants. Injury to the host plants is caused by the adults devouring the leaves and stems and the larvae eating the roots.

It resembles the better-known spotted cucumber beetle but is a trifle smaller, more yellow, and marked differently (Fig. 236). Extreme variation in color pattern occurs.

Fig. 236. The bean leaf beetle, *Cerotoma trifurcata* (Förster), adults and larva. Note variation in color pattern of adult. (Isely, Ark. Agr. Exp. Sta.)

Hibernation is in the adult stage in the soil or under crop remnants. With the coming of warm weather the beetles emerge and begin feeding and ovipositing. The orange eggs are placed in groups at the soil surface on or near the stems of the host plants. Hatching occurs in about eleven days, the slender white larvae then pass through three instars, transform to pupae, and emerge as adults. The complete life cycle requires 35 to 55 days. Only one generation occurs per year in the North but two and a partial third occur in the South.

The tachinid fly, *Celatoria diabroticae* (Shimer), often parasitizes about 20% of the adults. Cultural and mechanical control practices aid in checking this insect. Adjusting the planting date so that the young seedlings get started between the periods of high beetle population is also of value in control.

Insecticides commonly recommended for controlling this pest are carbaryl, DDT, or rotenone.

References: *Ark. Bul.* 248, 1930; *S. C. Bul.* 265, 1930.

BEAN APHID

Aphis fabae Scop., Family Aphididae

This blue-black plant louse (Fig. 29) is often found on dock, nasturtium, and other plants, but occasionally becomes abundant on vegetable crops, such as beans, to such an extent that serious loss results. Continuous feeding causes the leaves to turn yellow and the plants to become dwarfed and malformed.

In the fall eggs of the species are placed on woody plants, *Euonymus*

spp. and *Viburnum* spp. being the common winter hosts. In the spring these eggs hatch into wingless, parthenogenetic females that give birth to similar individuals. After a few generations, winged forms appear and fly to the summer hosts. Repeat generations occur throughout the summer, and with the coming of cool fall weather winged forms again appear, which fly to the winter hosts where sexual forms are produced that lay the overwintering eggs.

Should chemical control measures become necessary apply demeton, diazinon, malathion, mevinphos, naled, or parathion.

12

Insects Injurious to Solanaceous Crops

TOBACCO AND TOMATO HORNWORMS

Order Lepidoptera, Family Sphingidae

Hornworms are among the most destructive and widely distributed pests of tobacco and tomato plants. Even where they are not abundant these giant caterpillars may do a vast amount of damage, since each individual consumes a large quantity of food to reach full development (Fig. 237).

Two species are found in most infestations and though they bear a close resemblance each has its distinguishing features. The tobacco hornworm, *Manduca sexta* (Johan.), has seven diagonal stripes on each side of the body and the horn is curved and red, whereas the tomato hornworm, *M. quinquemaculata* (Haworth), has eight curved stripes and the

Fig. 237. Larvae of the tobacco hornworm feeding on tomato.

Fig. 238. Above, the tomato hornworm, *Manduca quinquemaculata* (Haw.): *a*, moth, *b*, larva, and *c*, pupa. Below, larva of the tobacco hornworm, *M. sexta* (Johan.). (Howard, U.S.D.A.)

horn is straight and black (Fig. 238). These caterpillars are usually green but some brown or nearly black individuals occur; when fully grown they attain a length of almost 4 inches. The adults are large fast-flying hawk moths, which in flight are sometimes mistaken for humming-birds. They have a wingspread of about 5 inches, and they may be seen at dusk hovering over flowers sucking nectar.

Overwintering occurs in the soil as dark brown pupae, measuring nearly 2 inches. Adults emerge in late spring and deposit spherical green eggs on the undersides of the leaves. In five days hatching occurs and the

larvae molt four or five times, reaching full development in three or four weeks. Pupation occurs in the soil and two to four weeks later adults emerge and lay eggs for a second generation. There may be one to four generations per year, depending on the latitude. The tobacco worm is generally distributed, whereas the tomato worm is more southern in its range, occurring only sparingly in the middle states region.

As soon as harvesting is completed the elimination of crop residues by immediate plowing will reduce the overwintering population of hornworms. A braconid parasite, *Apanteles congregatus* (Say), is an important natural enemy. Its white cocoons, attached externally to the worms, are familiar to the layman (Fig. 34). Numerous other natural enemies aid in control, particularly the stilt bug, *Jalysus spinosus* (Say), which attacks eggs.

In gardens and small plantings the most economical control measure is often found to be hand-picking. On both tomatoes and tobacco any one of the following chemicals gives control: carbaryl, TDE, endosulfan, guthion, parathion, or toxaphene. Follow all precautions in using highly toxic guthion or parathion. *Bacillus thuringiensis* has given good control in some regions, particularly against the smaller larvae. This holds true for the other insecticides; therefore all applications of insecticides should be made when the worms are small.

References: *U.S.D.A. Leaflet* 336, 1953; *Home and Garden Bul.* 46, 1963; *Ann. Ent. Soc. Amer.*, 52:741–755, 1959.

TOBACCO BUDWORM

***Heliothis virescens* (Fabr.), Family Noctuidae**

The budworm of tobacco is one of the more important pests with which the grower of that crop has to contend. In addition it may also attack cotton, tomatoes, garden peas, and other plants. This native insect of rather wide distribution is more prevalent in the South.

The injury done by this insect is destruction of the bud or growing tip of the plant and proves most serious when the plants are young. Where the bud is not entirely destroyed, the leaves growing from it are likely to be ragged and worthless. In many sections the damage from this insect exceeds that of all others.

The budworm overwinters as a pupa in the soil. Adult moths emerge in the spring and lay tiny white dome-shaped eggs on the undersides of tobacco leaves. Hatching occurs in approximately five days. The caterpillars, varying from light to dark green or even brown, with paler stripes running lengthwise of the body, begin devouring the host plants. Development is complete in eighteen to thirty-one days, after which they leave the plants, crawl in the soil, and pupate. Six to twelve days are spent in the brown pupal stage; then the new adults begin emerging. The adult

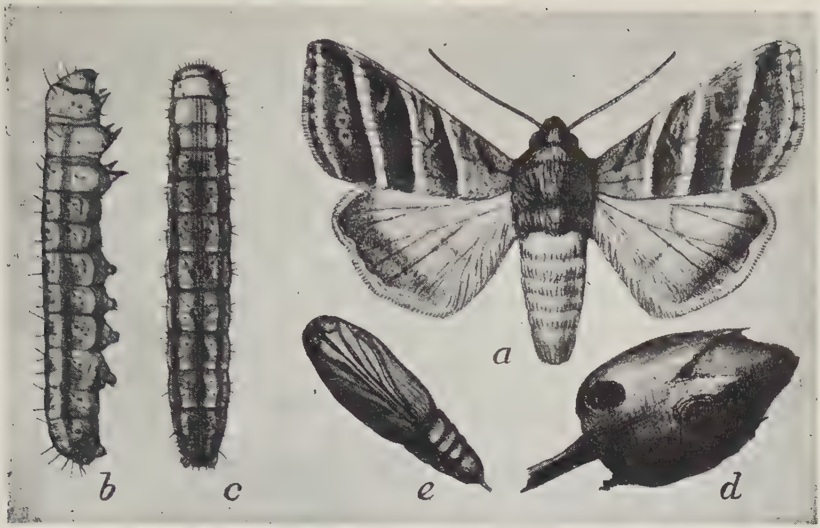


Fig. 239. The tobacco budworm, *Heliothis virescens* (Fabr.); *a*, adult moth; *b* and *c*, side and top view of larva; *d*, injured bud; and *e*, pupa. (U.S.D.A.)

moths have green fore wings obliquely crossed with three lighter stripes; the hind wings are silvery and are bordered with brown hairs (Fig. 239). About three generations develop on tobacco, and two late-season generations follow on other hosts. The adults and larvae of the corn earworm closely resemble these stages of the tobacco budworm.

Some natural control results from predatory spiders and wasps, and, most important, the parasitic braconid wasp, *Cardiochiles nigriceps* Viereck.

Cultural practices that contribute to budworm control are topping plants, plowing tobacco fields in the fall or winter, and destroying all plants in the field after harvesting is completed and all plants in seedbeds as soon as the beds are abandoned.

Chemical control measures should begin as the eggs and young budworm larvae are noticed, and repeated applications made at weekly intervals as needed. Usually two to four applications are sufficient. Recommended insecticides are carbaryl, DDT, TDE, and endosulfan applied as sprays or dusts. An older and more tedious control method is baiting. Baits are prepared by mixing 2 pounds of 50% WP DDT or TDE in 75 pounds of corn meal, or 1 pound of *Bacillus thuringiensis* WP (containing 30 billion spores per gram) in 9 pounds of corn meal. The bait is placed in the buds by hand, a pinch being applied to each bud, at the rate of 10 pounds per acre. Repeat applications as often as necessary to secure control.

Reference: *U.S.D.A. Farmers' Bul.* 2174, 1962.

OTHER TOBACCO PESTS

Corn Earworm, *Heliothis zea* (Boddie), is sometimes called the false budworm. It devours tobacco in much the same way as the budworm and each year may cause widespread damage late in the season to flue-cured varieties. Damage is most likely to occur where growers allow hairy vetch to mature near tobacco plantings. Control measures are the same as for the tobacco budworm (p. 287).

Tobacco Thrips, *Frankliniella fusca* (Hinds), (Fig. 240) feed on many plants, including wheat and cotton, but are likely to damage tobacco the most, especially in dry years. Adults and nymphs produce gray or silvery

Fig. 240. The tobacco thrips, *Frankliniella fusca* (Hinds). (U.S.D.A.)

feeding marks, principally along the veins of the lower leaves, with their rasping-sucking mouthparts. Heavy infestations cause the foliage to turn yellow. Injury may be more pronounced when the leaves are cured. Eggs of thrips are deposited in the leaf tissues; the young reach maturity in a little more than a week, and there are several overlapping generations each year. Adult thrips pass the winter inside stems of grasses and other plants, on or near the ground. Satisfactory control results from sprays or dusts of TDE or DDT, as recommended for budworm.

Reference: *Conn. Cir.* 179, 1950.

Suckfly, *Cyrtopeltis notatus* Distant, attacks tobacco grown for flue-curing in many parts of the South. Periodically it becomes abundant enough to cause serious damage in late-planted fields. Its feeding may reduce the coloration, weight, and thickness of the cured leaves, as well as lower the quality because of specks of excrement on the undersides. Control of this green-black slender plant bug should be effected by applying parathion at 0.15 pounds per acre.

One-spot Stink Bug, *Euschistus variolarius* (P. de B.), and occasionally

other species of stink bugs sometimes attack tobacco and tomatoes. Removal of plant sap by the piercing-sucking nymphs and adults (Fig. 241), near the point where the leaf petiole joins the main stalk, results in wilting. This bug is also said to be predaceous on other insects. If control measures become necessary, the insecticides suggested for stink bugs (p. 261) are recommended.

Green Peach Aphid, *Myzus persicae* (Sulz.), attacks tobacco wherever it is grown, particularly where the crop is shade-grown. The areas most seriously affected are in Georgia, Florida, and the Connecticut Valley. Aphid feeding causes curled, stunted, distorted leaves that become contaminated with cast molt skins, honeydew, and sooty fungus. This damage

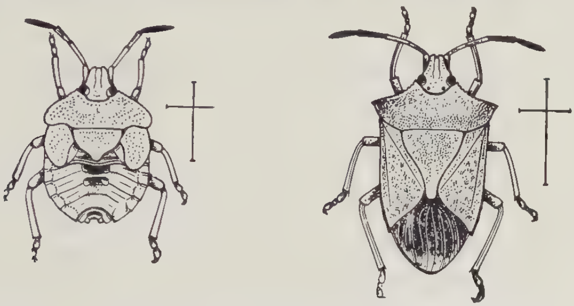


Fig. 241. One-spot stink bug, *Euschistus variolarius* (P. de B.): nymph (left), adult (right), enlarged. (U.S.D.A.)

quickly ruins a cigar-wrapper crop. In addition to the damage inflicted by sucking plant sap, aphids are important in the transmission of viruses causing disease in tobacco. The life cycle of this insect is covered on p. 484. Suggested control chemicals are endosulfan, malathion, and parathion applied to the foliage when the need arises.

References: *U.S.D.A. Leaflet* 405, 1957; *Tech. Bul.* 1175, 1958; *Ohio Agr. Exp. Sta. Res. Cir.* 50, 1958.

Grasshoppers, cutworms, stalk borers, plant bugs, wireworms, and seed corn maggots may attack tobacco. Discussion and control of these pests are found elsewhere in this book.

FLEA BEETLES

Order Coleoptera, Family Chrysomelidae

Serious injury to tobacco, potato, and eggplant results from the feeding of flea beetles and their larvae; occasional injury is observed on tomato, pepper, and related plants, but it is usually not as severe. Adult beetles

chew small holes in the leaves, giving them a sieve-like appearance; the larvae feed on the underground parts of their host plants. Some species, particularly those of the tuber flea beetle, scar the surface of potato tubers or bore into them and cause discoloration, resulting in waste when the potatoes are pared. Potato flea beetles are also known to be vectors of the organisms causing spindle tuber, blight, brown rot, and potato scab. Tobacco is seriously damaged both in the seed bed as well as the field. Adult feeding substantially reduces the market value of tobacco grown for cigar wrappers.

Important species are the potato flea beetle, *Epitrix cucumeris* (Harris) (Fig. 242), the eggplant flea beetle, *Epitrix fuscula* Crotch, the tobacco flea beetle, *Epitrix hirtipennis* (Melsheimer) (Fig. 243), the western potato flea beetle, *Epitrix subcrinita* (LeConte), and the tuber flea beetle, *Epitrix tuberis* Gentner. The potato flea beetle is generally distributed; the tobacco and eggplant flea beetles range over a large area but are usually more southern. Tuber flea beetles are potato pests primarily in Washington, Oregon, Colorado, Nebraska, British Columbia, and Vancouver Island. Little damage to other crops is caused by this species. The western potato flea beetle is found primarily in western United States.

Adults of the various flea beetles are approximately $\frac{1}{16}$ inch in length. Some are entirely black, others brown-black with faint lighter markings. These hibernate in the soil, crop remnants, or other vegetation and become active in the spring, feeding on the host plants as new growth appears. Consequently, early injury is likely to be severe. Eggs are laid

Fig. 242. The potato flea beetle. (U.S.D.A.)

Fig. 232. The tobacco flea beetle, *Epitrix hirtipennis* (Melsh.). (U.S.D.A.)

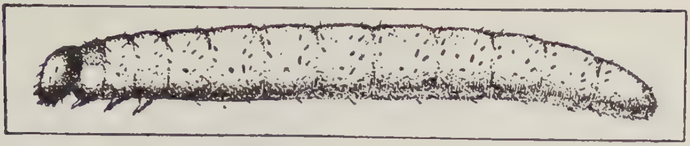


Fig. 244. Larva of the potato flea beetle; greatly enlarged. (Johannson.)

on or in the soil near the base of the plant. These hatch in about a week and the slender white larvae (Fig. 244) feed on the plant roots or tubers for a period of two or three weeks, after which pupation occurs, followed by emergence of the new adults. The entire life cycle from egg to adult may be completed in six weeks or less. One to four generations develop each year, depending on the species and on the region of the country in which they occur. Feeding by the adults may extend over a period of two months.

Natural control of flea beetles results primarily from the climatic factors that limit their numbers and distribution. Screening tobacco seed beds with cloth furnishes excellent protection to the young seedlings. Insecticides are necessary to combat these insects and the one selected depends on the crop to be protected and whether resistance has developed from continued use of a particular chemical. For potatoes, where residues are not a problem, sprays or dusts of DDT are economical and quite satisfactory.

At least 1 pound of DDT must be applied per acre per application. This requires 20 pounds of 5% DDT dust, 2 pounds of 50% DDT wettable powder, or 2 quarts of 25% DDT emulsifiable concentrate. Applications should start when the plants are about 4 inches tall and should be repeated several times at seven- to ten-day intervals, to kill the adults before egg-laying occurs. Should control with DDT be unsatisfactory, substitute 6 to 8 ounces of dieldrin per acre. Other recommended chemicals for potatoes are carbaryl, endosulfan, guthion, parathion, phosphamidon, phorate, and Di-Syston. On tobacco, DDT, TDE, and guthion are suggested chemicals; treatment of the seed beds is often necessary. For controlling flea beetles on eggplant, tomatoes, and peppers, apply carbaryl, DDT, endosulfan, methoxychlor, toxaphene, or rotenone. Insecticides containing technical DDT have a stunting effect on tomatoes; therefore the nonphytotoxic aerosol or purified grade of DDT should be substituted on this crop.

References: *Can. Dept. Agr. Pub.* 94, 1949; 96, 1951; *Va. Agr. Exp. Sta. Bul.* 355, 1943; *Conn. Agr. Exp. Sta. Cir.* 179, 1950; *U.S.D.A. Farmers' Bul.* 2168, 1965; *Agr. Handbook* 264, 1964; *J. Econ. Ent.,* 49:530–533, 557–558, 1956.

POTATO LEAFHOPPER

Empoasca fabae (Harris), Family Cicadellidae

The potato leafhopper is considered the most important of all the insect pests of this crop in the United States. Besides potatoes it also seriously damages beans, alfalfa, clover, cotton, and deciduous nursery stock. It is also known to feed on nearly 200 other kinds of plants. This hopper occurs throughout the United States, with the possible exception of the Northwest, but is most abundant east of the Rocky Mountains. From western Texas to the Pacific Coast, the closely related species, *Empoasca abrupta* DeL., *E. arida* DeL., *E. solana* DeL., and *E. filamenta* DeL., are more common.

Feeding by this leafhopper on potatoes, eggplant, rhubarb, and dahlia causes curling, stunting, and dwarfing, accompanied by a yellowing, browning, or blighting of the foliage known as hopperburn or tipburn. This is caused by the injection of saliva into the phloem during feeding which results in a physiological disturbance producing disease-like manifestations. On beans and other hosts, a marked curling-under of the leaf edges is produced, and a crinkling effect of the upper surface along with the usual stunting effects already described.

The adult is pale green, somewhat wedge-shaped, about $\frac{1}{8}$ inch long with inconspicuous white spots on the head and pronotum. Adults are very active, jumping or flying when disturbed. Both nymphs and adults can run backwards or sideways as rapidly as they move forward. The females deposit slender white eggs within the stems and larger veins of the leaves. Hatching occurs in six to nine days during the summer, and the pale green nymphs molt four times before they become fully grown and transform to winged adults (Fig. 245). Shortly after the adults appear, mating takes place, followed by oviposition. The period from egg to adult is about three weeks during warm weather; several overlapping generations develop each season. The potato leafhopper has not been found overwintering north of the Gulf states where it breeds throughout the year. Migration northward with the warm spring winds occurs annually. In Ohio the first adults usually appear in mid May. Adults have been collected in late April as far north as Wisconsin.

The most common insecticide for control of leafhoppers on potatoes is DDT. Apply 1 pound of actual DDT per acre in either emulsifiable, wettable powder, or dust formulations. Begin the treatment when leafhoppers appear on the plants and repeat with several applications at ten-day intervals. DDT may be used on any host plant for controlling leafhoppers, but on beans, alfalfa, or other crops where poisonous residues may be a problem, methoxychlor is suggested at 1.5 pounds per acre. For small garden plantings dusts containing 5% DDT or 5% methoxy-

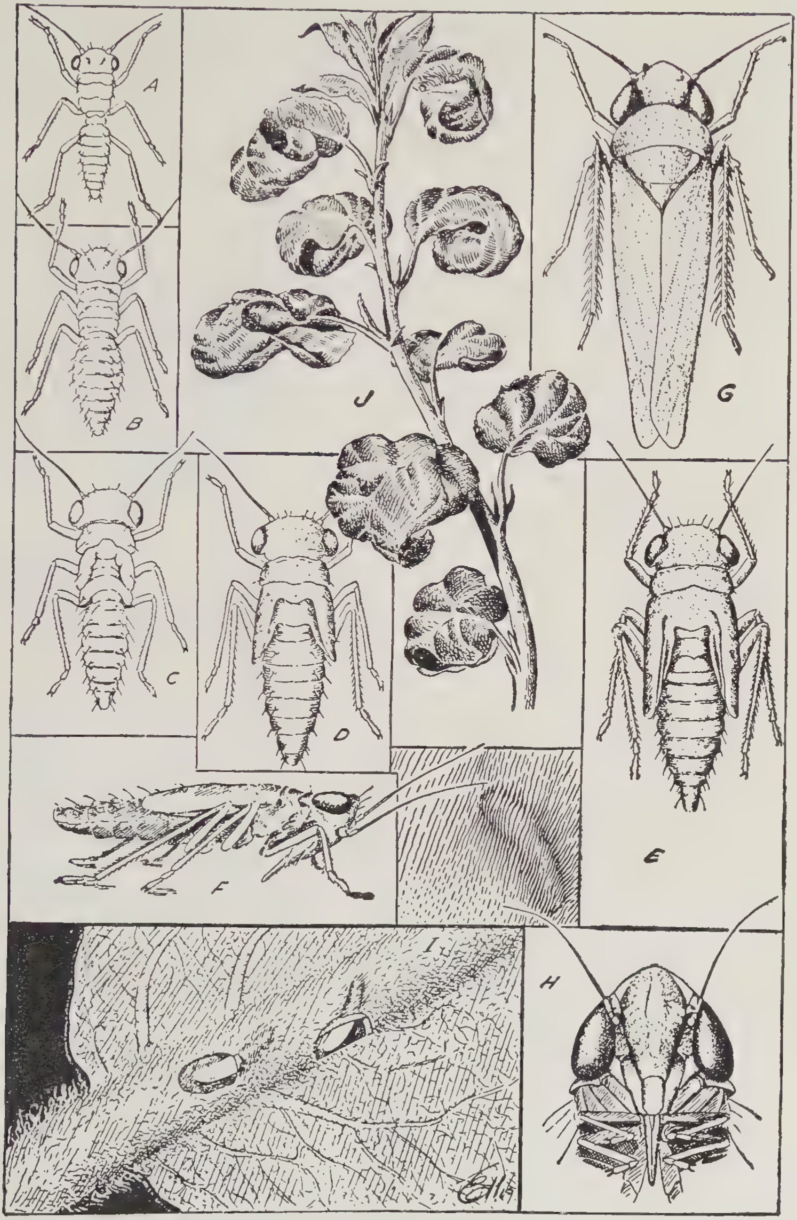


Fig. 245. The potato leafhopper, *Empoasca fabae* (Harris): *A*, first nymphal stage; *B*, second stage; *C*, third stage; *D*, fourth stage; *E*, fifth stage; *F*, side view of fifth stage; *G*, adult; *H*, front view of head of adult; *I*, eggs in tissue on underside of apple leaf; *J*, curled condition of terminal leaves owing to attack by the leafhopper on apple. (Ackerman, U.S.D.A.)

chlor have been adopted widely with satisfactory results. Other recommended chemicals, especially for application to beans, are carbaryl, malathion, and parathion.

References: *U.S.D.A. Tech. Bul.* 618, 1938; *Farmers' Bul.* 2168, 1965; *Leaflet* 229, 1952; 521, 1963; *Agr. Handbook* 264, 1964; *Ann. Ent. Soc. Amer.*, 57:588–591, 1964.

COLORADO POTATO BEETLE

Leptinotarsa decemlineata (Say), Family Chrysomelidae

Universally known among growers as the potato bug, this insect was long considered the most dangerous enemy of potatoes and is still capable of doing much damage. In commercial potato-growing areas, where spraying for disease and leafhopper control is a regular practice, insecticides have so reduced the population that it is no longer a serious problem. How great a part natural control has played in bringing about this condition has not been determined. Nevertheless, in some places the control of this insect still demands attention.

The Colorado potato beetle is an invader from the semiarid regions of eastern and southern Colorado. It fed originally on a species of *Solanum,* called the sandbur. When the early settlers planted potatoes within the range of the insect, it promptly attacked them and thrived so well that it multiplied far beyond the original numbers; it then migrated eastward, following the potato plantings. This was before insecticides and spraying methods had been developed. The absolute necessity for control led to the first use of arsenicals, such as paris green and London purple.

The adults are stout, oval, strongly convex beetles, about $\frac{3}{8}$ inch long, with black and yellow stripes running lengthwise along the wing covers (Fig. 246). The ten black stripes suggested the specific name *decemlineata.* Overwintering beetles hibernate in the soil, emerging in the spring about the time that potatoes come through the ground. They lay orange-yellow eggs in groups of a dozen or more on the undersides of the leaves, each female depositing approximately 300 over a five-week period. In a few days hatching occurs, and the dark red larvae devour the foliage, becoming orange-colored as maturity approaches. There are two rows of conspicuous black dots on the sides of their bodies. The larvae are often called soft bugs or grubs by growers of potatoes. When mature they leave the plant, enter the soil and pupate, emerging as adults several days later. The life cycle requires about a month, and there are one to three generations per year, depending on the latitude. Injury is due to actual consumption of foliage and stems by the chewing adults and larvae. The adult is said to be one of the agents in the spread of organisms causing the diseases spindle tuber, bacterial wilt, and ring rot of potatoes.

Control is accomplished by applying DDT, carbaryl, guthion, endosulfan, naled, or phosphamidon. Where resistance to the chlorinated hydrocarbons has developed, change to carbaryl, guthion, or phosphamidon.

References: *U.S.D.A. Farmers' Bul.* 2168, 1965; *Agr. Handbook* 264, 1964.

Fig. 246. The potato beetle, *Leptinotarsa decemlineata* (Say) (larva in insert). (U.S.D.A.)

Fig. 247. The potato aphid, wingless summer form. (Ohio Agr. Exp. Sta.)

POTATO APHID

Macrosiphum euphorbiae (Thomas), Family Aphididae

This insect is also called the pink and green potato aphid because it occurs in two color phases. Damage is caused by both nymphs and adults sucking plant sap from the foliage, especially the terminal growth. In addition, this aphid may carry and transmit the virus organisms causing leaf roll, mild mosaic, rugose mosaic, spindle tuber, and unmottled curly dwarf from diseased to healthy plants. Besides potato, this aphid also attacks tomato, eggplant, pepper, sunflower, jimson weeds, and many other plants. It is found throughout the United States and southern Canada.

In the North, winter is passed in the egg stage, principally on wild rose bushes. These black eggs hatch in the spring into wingless females which give birth to young. As the season progresses both winged and wingless individuals develop, the winged ones dispersing to various hosts including potatoes. Here generations occur throughout the summer. With the coming of cool weather in autumn, winged individuals fly to the winter hosts, produce oviparous females which mate and deposit the overwintering eggs. Many generations occur throughout the summer in the North, and in the South the number is even larger with no sexual

generations developing at all. The pink or green wingless adult (Fig. 247), is about $\frac{1}{6}$ inch in length with long legs and prominent cornicles.

Other aphids attacking potatoes, peppers, and related hosts are the green peach aphid, *Myzus persicae* (Sulzer), the buckthorn aphid, *Aphis nasturtii* Kltb., and the foxglove aphid, *Acyrthosiphon solani* (Kaltenbach). They have life cycles similar to that of the potato aphid.

Aphids have many natural enemies that often keep populations checked. If a serious infestation develops, apply one of the following pesticides: endosulfan, phorate, diazinon, demeton, malathion, parathion, or Di-Syston. Di-Syston or phorate are applied as granules in the furrow at planting time. Where aphids are a problem every year foliage applications must begin early to maintain control.

References: *U.S.D.A. Farmers' Bul.* 2168, 1965; *Agr. Handbook* 264, 1964; *Tech. Bul.* 1338, 1965.

POTATO TUBERWORM
Phthorimaea operculella (Zeller), FAMILY GELECHIIDAE

The tuberworm is of cosmopolitan distribution, occurring in most areas where potatoes or other solanaceous plants are grown or shipped. It has been found in almost every state in the United States, but it has been reported causing serious damage primarily in California, Maryland, and Virginia.

Damage consists of foliage injury caused by the larvae mining between

Fig. 248. Potato section showing injury by potato tuberworm. (U.S.D.A.)

Fig. 249. The potato tuberworm, *Phthorimaea operculella* (Zeller); moth and larva. (U.S.D.A.)

the leaf surfaces and in the stems. On tobacco this injury is known as "splitworm" damage. Severe loss of the tubers also results, both in the field and in storage, owing to the larval tunnels which are contaminated with excrement and permit the entrance of decay organisms (Fig. 248).

The adult is a small gray moth with a wing expanse of about $\frac{1}{2}$ inch. The wings are narrow, fringed with hairs, and mottled with black and brown spots (Fig. 249). Larvae are slender, chewing caterpillars with dark heads and white bodies which are sometimes tinged with pink or green. The winter is passed as larvae or pupae in the soil, where the weather makes hibernation necessary; in California, all stages are said to be present at all seasons in the infested districts. Moths emerge with the coming of warm weather and begin laying white eggs on potato, tobacco, eggplant, and related weeds. These hatch in a few days and the larvae pass through four instars in reaching full development, then pupate in the soil and emerge a few days later. The average time required to produce a generation is twenty-five to thirty days. Several generations are produced each season, the later ones attacking tubers which are exposed or only lightly covered with soil. In storage, the insect may continue to breed, provided that the temperatures are approximately 50° F. or above.

Cultural practices that are of value in controlling the tuberworm are: plant the spring crop early, keep the developing tubers covered with at least 2 inches of soil, harvest as early as possible, avoid leaving exposed potatoes in the field overnight, destroy all infested or discarded potatoes which may serve as breeding material, avoid planting the fall crop adjacent to spring plantings, and arrange for prompt marketing.

Spraying with 2 pounds of 50% DDT wettable powder or 1 quart of 25% emulsifiable concentrate to 100 gallons of water per acre controls

this pest in the field. A 5% DDT dust at 20 to 30 pounds per acre is also satisfactory. Application should be made when foliage injury is noticed. Potatoes receiving a regular spray program for disease and insect control will be protected, provided that DDT is in the schedule. Other effective control chemicals are endosulfan and guthion.

Potatoes stored at temperatures of 50° F. or lower will not be damaged by tuberworms, but if storage is at that temperature development is only arrested and will resume when higher temperatures prevail.

Residual sprays of 2.5% DDT applied to the storage area is an essential control operation. DDT-impregnated bags also prevent damage while potatoes are in storage. Seed potatoes may be protected by dusting with 4 ounces of 3% DDT dust to 100 pounds of potatoes. A three-hour exposure to the vapors of methyl bromide at a concentration of 2 pounds per 1000 cubic feet of space will eliminate an established infestation in storage.

References: *Va. Bul.* 251, 1926; *Va. Truck Exp. Sta. Bul.* 61, 1927; 111, 1949; *U.S.D.A. Farmers' Bul.* 2168, 1965; *Agr. Handbook* 264, 1964.

MISCELLANEOUS PESTS

Blister Beetles, discussed as pests of legumes (p. 270), occasionally attack potatoes. There are several species that injure solanaceous crops, but the most common are the black blister beetle, *Epicauta pennsylvanica* (DeG.), the striped blister beetle, *E. vittata* (Fabr.) (Fig. 250), the margined blister beetle, *E. pestifera* Werner, the ebony blister beetle, *E. funebris* Horn, the ash-gray blister beetle, *E. fabricii* (LeConte), and the spotted blister beetle, *E. maculata* (Say). Damage is caused by the adults which sometimes appear in great numbers in midsummer and begin feeding voraciously. The larval stages are beneficial since they feed on grasshopper eggs in the soil. Adults have been known to infect potatoes with

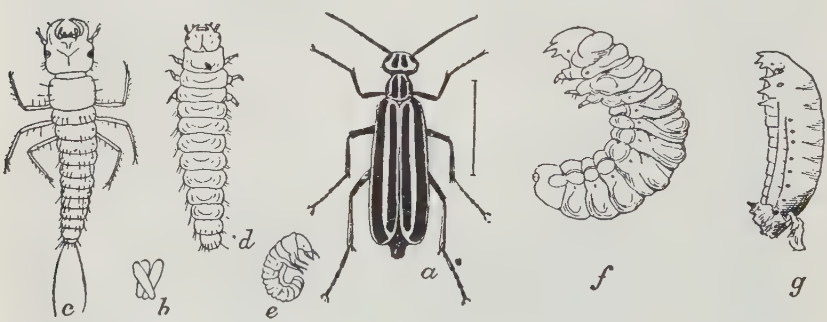


Fig. 250. The striped blister beetle, *Epicauta vittata* (Fabr.), which destroys eggs of grasshoppers. Eggs, *b;* larvae, *c, d, e, f;* pupa, *g;* and adult, *a.*

organisms causing brown rot. Usually only one generation is produced each year.

Chemical control is accomplished by applying the following chemicals directly to the beetles: DDT, naled, parathion, or toxaphene. Potatoes receiving a regular spray program are seldom damaged.

Wireworms have been discussed as enemies of other plants (p. 139). As pests of solanaceous crops, particularly tobacco and potatoes, these insects often are of special importance. Several species may be responsible for causing damage, the relative abundance of each depending on the locality. On tobacco, the newly set plants show the most noticeable injury. Their roots and crowns are destroyed and the worms may even burrow up into the stems. On potatoes, damage to seed pieces soon after planting may be so serious as to reduce the stand. Later the wireworms chew deep pits and tunnels in the developing tubers, decreasing the market value of the crop (Fig. 251). This injury also favors the spread of rhizoctonia or other diseases affecting potato tubers.

Older control methods have been: rotation of crops, fallowing, soil fumigants, and crop management. Chemical control measures consist of treating the soil with diazinon, parathion, chlordane, or DDT. Apply to the soil surface and mix the chemical with the top 4 to 6 inches by disking. One application just before planting gives protection for the entire growing season. The DDT treatment will last several years.

White Grubs likewise are pests of other plants as well as potatoes. Damage to potatoes is often the result of planting in grub-infested soil, the injury consisting of large shallow holes made in the tubers by the larvae (Fig. 252). The affected plants do not reveal the injury. The description of the common species and their life cycles is given in Chapter

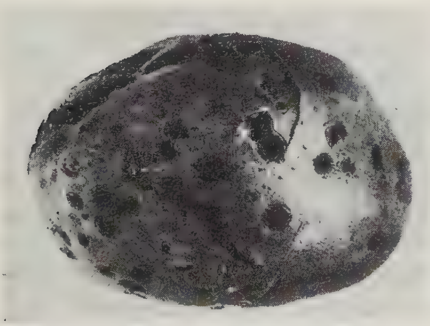


Fig. 251. Potato injured by wireworms. (Cornell Agr. Exp. Sta.)

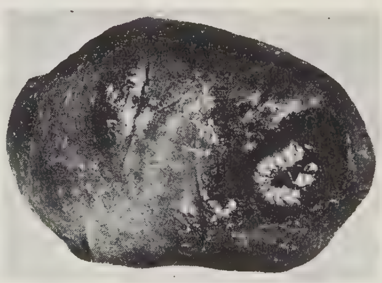


Fig. 252. A white grub working in a potato, showing typical damage. (Davis, U.S.D.A.)

8 (p. 136). Besides avoiding the planting of potatoes in soils previously in sod and known to be infested, chlordane and DDT, as indicated for wireworms, will control white grubs, provided that higher dosages are applied. It may be necessary to increase the dosages slightly for heavily infested soils. Mix the insecticides thoroughly with the upper soil layers for maximum effectiveness.

Three-Lined Potato Beetle, *Lema trilineata* (Olivier), is a leaf beetle about $\frac{1}{4}$ inch in length, yellow in color, with three black stripes on the back (Fig. 253). It is sometimes found feeding on potatoes but is more common on related weed hosts. The larvae have the habit of forming a

Fig. 253. The three-lined potato beetle, *Lema trilineata* (Olivier). (U.S.D.A.)

mass of granules of their own excrement which serves as a shield over the greater part of their bodies. Where potatoes are sprayed regularly for other pests this insect will not be found. Arsenicals or DDT control it if treatment is necessary on other hosts.

Potato Stalk Borer, *Trichobaris trinotata* (Say), feeds in the stems of several solanaceous plants and is occasionally destructive to eggplant and potato plantings. The adults are snout beetles, $\frac{3}{16}$ inch in length, black with gray pubescence over the body except for three spots at the base of the wing covers and the head (Fig. 254). Overwintering adults emerge from hibernation in the spring, feed on the foliage, and lay eggs on the stems of potatoes or other hosts. On hatching the pale yellow larvae with brown heads burrow into the stalks, causing the greatest damage. By late July pupation occurs and transformation to adults takes place within

the burrows where they normally remain until the following spring. Destruction of vines after harvest is of value in control. Potatoes receiving a regular spray program are not damaged by this pest. Injury to other hosts may be prevented by spraying or dusting with DDT or methoxychlor.

Green June Beetle, *Cotinis nitida* (L.), is a large green species well known in the southern states. Adults devour the foliage and fruits of a

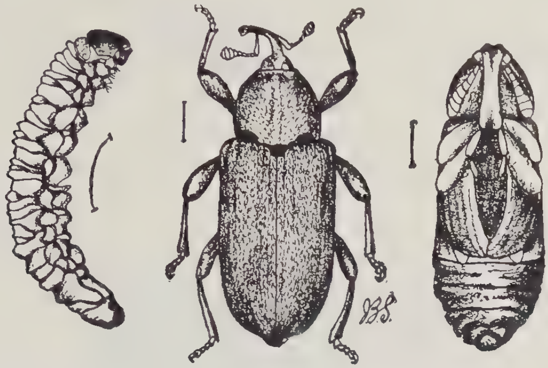


Fig. 254. Potato stalk borer, *Trichobaris trinotata* (Say); larva, pupa, and adult. (J. B. Smith.)

Fig. 255. Larva of the green June beetle, *Cotinis nitida* (L.). (U.S.D.A.)

number of trees, shrubs, and small fruit crops. The large larvae, somewhat like ordinary white grubs (Fig. 255), loosen the soil about plants and may feed on their roots. Grasses, legumes, tobacco in plant beds, and other plants growing in soils very high in decaying organic matter are most often injured. Seedling plants may be damaged so severely as to reduce the stand. The larvae have the habit of crawling on their backs. Hibernating larvae pass the winter deep in the soil, then tunnel near the surface in the spring where feeding takes place. Pupation occurs in late spring and adults begin emerging in June. Adult abundance is greatest in July and August. Eggs are deposited in the soil, and the young grubs hatching from them feed until cold weather comes. One generation develops each year.

Control measures are directed toward killing the larvae in the soil. Tobacco beds may be fumigated, drenched, or baited. Methyl bromide is an effective fumigant when used at the rate of 9 pounds to each 100 square yards. Probably the easiest way to control larvae is to drench the infested area. A drench can be prepared by mixing water with 50% powder formulations of carbaryl or Dylox and 25% powder formulations of endosulfan or diazinon; use 1 pound of powder of one of these chemicals in 100 gallons of water and apply with a sprinkling can at the rate of 1 gallon per square yard. The bait can be made by mixing thoroughly 1 pound of 50% Dylox with 25 pounds of wheat middlings and enough water to make a crumbly mash, usually 2 to $2\frac{1}{2}$ gallons. Sprinkle the area to be treated with water and broadcast the bait in the afternoon at the rate of 18 pounds per square yard of infested area.

Soil treatment of large areas may be accomplished by broadcasting granular formulations of aldrin, carbaryl, chlordane, diazinon, dieldrin, Dylox, endosulfan, heptachlor, methyl parathion, or toxaphene at dosages recommended on the label of the package. Selection of the proper chemical will depend somewhat on possible hazards involved in the areas to be treated. The early larval instars may be killed by lower dosages of these chemicals.

References: *N.C. Agr. Exp. Sta. Bul.* 242, 1921; *Va. Agr. Exp. Sta. Bul.* 454, 1952; *J. Econ. Ent.*, 46:705–706, 766–771, 1953; 50:96–100, 1957; *U.S.D.A. Leaflet* 504, 1962.

Potato Psyllid, *Paratrioza cockerelli* (Sulc), occurs in most of the western states except Oregon and Washington, and is an important pest of potato and tomato in Colorado, Utah, Nebraska, and New Mexico. Other solanaceous plants may also serve as hosts. Besides the removal of plant sap by the nymphs and adults, this feeding results in curled yellow leaves known as psyllid yellows. The set of tubers is increased, but they are usually too small to be marketable. Aerial tubers sometimes form in the leaf axils.

Adult psyllids pass the winter in Texas and New Mexico, with development occurring on weeds in the nightshade family. In the spring, migration northward takes place as the season advances, adults appearing in Colorado and Utah in May and June.

The light yellow eggs are spindle-shaped and suspended from the leaves on short stalks. These hatch in three to eight days, and the flattened, scale-like, pale yellow-green nymphs pass through five instars in fifteen to twenty days before transforming to adults. The adult resembles a tiny cicada (Fig. 256), about $\frac{1}{10}$ inch long with four membranous wings held rooflike over the body. There may be ten or more generations per year.

When one or more adult psyllids are caught in 100 sweeps of an insect net, it is advisable to begin treatment with DDT or parathion.

Four to five applications about two weeks apart are required where infestations are heavy.

References: *Colo. Bul.* 454, 1939; *Nebr. Bul.* 327, 1940; *U.S.D.A. Farmers' Bul.* 2168, 1965; *Tech. Bul.* 1107, 1955; *Agr. Handbook* 264, 1964.

Fig. 256. The potato psyllid, *Paratrioza cockerelli* (Sulc). (Knowlton, Utah. Agr. Exp. Sta.)

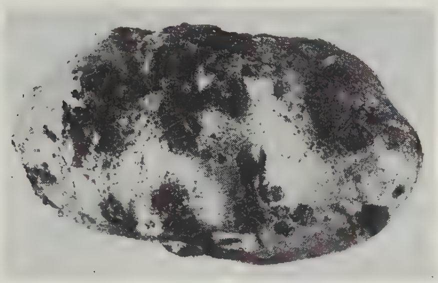


Fig. 257. Work of the potato scab gnat. (Ohio Agr. Exp. Sta.)

Potato Scab Gnat, *Pnyxia scabiei* (Hopkins), is a sciarid fly or fungus gnat, the larva of which is capable of causing serious injury to potatoes. Egg-laying adult females are attracted to decaying plant materials and the wounds in potato tubers that may have been caused by other insects or disease organisms. The white maggots attack seed pieces or growing tubers and continue to develop after harvest in the stored potatoes. The result is a condition that is described as scabby (Fig. 257). Adult females are wingless (Fig. 258); the males are winged. Overwintering gnats occur in stored potatoes and in the field. Development is rapid in warm weather; the entire life cycle may be completed in fifteen days. Although this pest is rather widely distributed in the northeastern and north central states, it is not a common pest of potatoes.

Disposing of infested tubers before planting time, treating seed with corrosive sublimate or hot formalin, rotating potatoes with less susceptible crops, where possible growing the crop in acid soil (about *p*H 5), selec-

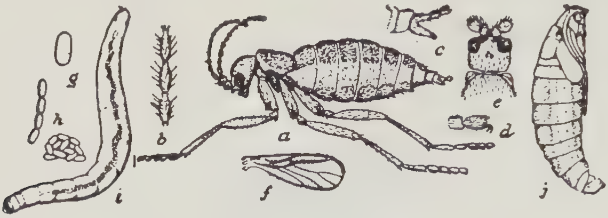


Fig. 258. Potato scab gnat, *Pnyxia scabiei* (Hopkins): *a*, female fly; *b*, antennal segments; *c*, tip of abdomen; *d*, tip of hind leg; *e*, head, dorsal view; *f*, wing of male; *g*, egg; *h*, egg mass; *i*, larva; *j*, pupa; much enlarged. (Hopkins, W. Va. Agr. Exp. Sta.)

Fig. 259. Tomato fruitworm feeding on a tomato. (U.S.D.A.)

tion of certified seed, preventing heating and sweating of tubers in bins, are all suggested control measures.

References: *Ohio Agr. Exp. Sta. Bul.* 524, 1933; *U.S.D.A. Farmers' Bul.* 1881, 1948; 2168, 1965; *Agr. Handbook* 264, 1964.

Tomato Fruitworm, *Heliothis zea* (Boddie), is merely the corn earworm attacking tomatoes. This insect feeds on tomato foliage and fruits, especially the green fruits which are often damaged so much that they are unmarketable (Fig. 259). Recommended control measures are the application of cryolite, carbaryl, DDT, TDE, toxaphene, or toxaphene plus

DDT. Repeat applications are usually required at one- or two-week intervals during heavy infestations. Follow all precautions concerning poisonous residues.

References: *U.S.D.A. Tech. Bul.* 1147, 1956; *Leaflet* 367, 1963; *J. Econ. Ent.*, 56:813–817, 1963.

Tomato Russet Mite, *Vasates lycopersici* (Massee), is a pest of tomatoes but may feed on other solanaceous hosts in the subtropical or tropical regions of the United States. When feeding on tomatoes the surface of the leaves and stems are russeted or bronzed in appearance. After three or four weeks of attack the main stalk of the plant cracks or checks and the leaves turn brown. If no control measures are initiated, the entire plant turns brown and dies.

Adult mites are orange-yellow, wedge-shaped, tapering posteriorly, about 200 microns in length, 50 microns in thickness, with a short piercing-sucking beak. At 70° F. development from egg to adult occurs in seven days. Reproduction is continuous where environmental conditions permit but slows down with cooler temperatures. All stages are killed by prolonged temperatures of freezing or below.

Control is accomplished by dusting all affected plants with 25% sulfur at 30 pounds per acre. In the more northern areas all tomato seedlings shipped from the South should be dusted with sulfur. Tests show that parathion, malathion, Kelthane, and toxaphene at commonly recommended dosages appeared to be as effective as sulfur for controlling russet mite. Repeat applications at two-week intervals are usually required.

References: *J. Econ. Ent.*, 36:706–712, 1943; 46:502–504, 1953; U.S.D.A. E-876, 1954; *Ann. Ent. Soc.*, 55:431–435, 1962.

Tomato Pinworm, *Keiferia lycopersicella* (Walsingham), is primarily a pest in warmer climates but may infest tomatoes grown in greenhouses in more northern areas. Damage is done by the larvae feeding as leaf miners, which occasionally invade the stems and fruits. In addition to the United States, pinworms occur in Mexico, Hawaii, Central and South America, and some of the West Indian islands.

The adults are small gray moths $\frac{1}{4}$ inch in length. They are more active at dusk and deposit their tiny oval eggs on any part of the plant but usually on the lower surface of the leaves. Hatching occurs in a week and the young larvae are light orange at first, becoming purplish black as maturity is reached, when they attain a length of $\frac{1}{4}$ inch. Pupation may occur in the soil, in the folded leaves, or in tomatoes. Adults emerge and soon begin laying eggs, the total length of the life cycle varying from three to six weeks, depending on the temperature.

Effective control can be attained by applying DDT, parathion, guthion,

Fig. 260. The pepper weevil, *Anthonomus eugenii* Cano: (left) adult; (right) larvae working in pepper fruits. (U.S.D.A.)

or toxaphene. Plowing under crop residues at the end of the growing season also reduces the population.

References: *U.S.D.A. Cir.* 440, 1937; *Ohio Res. Bul.* 702, 1950; *J. Econ. Ent.*, 52:155–158, 1963.

Pepper Weevil, *Anthonomus eugenii* Cano, is a Mexican insect that is established in Texas, New Mexico, California, Arizona, Georgia, and Florida. The adult is a snout beetle about $\frac{1}{8}$ inch in length, black in color but sparsely covered with gray or tan hairs (Fig. 260). It lays its eggs in the buds or young pods where the white larvae with brown heads feed and develop, rendering the peppers unmarketable. Pupation also occurs inside the peppers and adults emerge and begin the cycle anew. There may be five to eight generations per year, depending largely on the prevailing temperatures. DDT or toxaphene are the commonly recommended chemicals for control of pepper weevil.

References: *U.S.D.A. Leaflet* 226, 1942; *Farmers' Bul.* 2051, 1959; *Home & Garden Bul.* 46, 1963.

Pepper Maggot, *Zonosemata electa* (Say), is the larva of a tephritid fly, which was first observed in New Jersey in 1915. It is now found from New York and Massachusetts to Kansas and southward to Florida and Texas. The natural food of the insect is said to be the horse nettle, *Solanum carolinense.* Eggplants are sometimes attacked but serious injury has been done only to pepper. The slender white maggots feed within the pods, a single maggot rendering the peppers worthless for marketing.

The adults are two-winged, yellow-striped flies, about $\frac{3}{10}$ inch long. They deposit eggs beneath the skin of the peppers, and all larval development is completed inside. Pupation takes place in the soil at a depth of 2 to 4 inches, but the adults do not emerge until the following summer, starting sometime in July.

To control this pest, apply chlordane, malathion, parathion, or rotenone. Make the first application two or three days after the first flies appear in the field and repeat at five-day intervals as long as flies are found.

References: *N.J. Bul.* 373, 1923; *U.S.D.A. Farmers' Bul.* 2051, 1959.

13

Insects Injurious to Greenhouse, Flower, and Vegetable Crops

This chapter deals with some of the major insects and other pests that attack a wide variety of greenhouse and garden plants. Other insects that may attack the same plants are discussed in Chapters 8, 12, 16, and 21.

TWO-SPOTTED SPIDER MITE

Tetranychus urticae Koch, Family Tetranychidae

This widely distributed species is probably the most troublesome of all the spider mites. It feeds on many hosts including field, garden, greenhouse, nursery, and ornamental plants as well as weeds. All active stages remove plant sap, usually from the undersurface of the leaves, resulting in tiny light spots. This gives the foliage a speckled appearance, and with severe infestation the entire plant may be killed.

The spider mite is variable in color, usually with shades of green, yellow, or red, and two darker dorsal pigmented spots (Fig. 261). The first instar is pale yellow and has three pairs of legs. Later instars have four pairs of legs, the mature females being the larger of the two sexes and showing more pigmentation. Males are recognized by their greater activity, smaller size, and narrow, more pointed abdomen. Tiny clear to pale green spherical eggs are usually deposited on the undersides of leaves where feeding and spinning of delicate webs takes place. Hot dry weather favors rapid development of spider mites, whereas low temperature, high humidity, and excess moisture are unfavorable. Under ideal conditions, eggs may hatch in three days and after three molts the adult stage may be reached three days later. Ten generations develop out-of-

doors each year at Blacksburg, Virginia, and these overlap so much that all life stages are always present. In greenhouses reproduction is continuous throughout the year, with many generations developing. Out-of-doors in colder climates the hibernating orange-colored females and sometimes even the normal crawling stages remain throughout the winter. Each female mite may deposit nearly 200 eggs and may live nearly seventy days, but on the average about seventy eggs are deposited and longevity is thirty days. Unfertilized eggs develop into male mites.

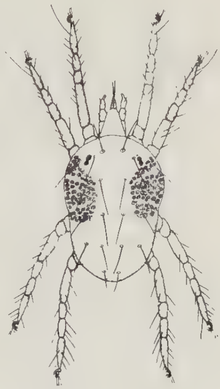


Fig. 261. Adult female two-spotted spider mite. (Cagle, Va. Agr. Exp. Sta.)

Predaceous mites in the genus *Typhlodromus* are very important in keeping mite populations checked. DDT and other chlorinated hydrocarbon insecticides are highly toxic to the predaceous but not the plant-feeding species; hence the latter become more abundant when such compounds are used. Frequent syringing of plants with a strong stream of water is of value in spider mite control, particularly on plants that can stand this treatment.

Dusting sulfur is effective as a miticide, especially during hot weather. The following are miticides now used on various crops: Aramite, binapacryl, carbophenothion, chlorbenside, chlorobenzilate, demeton, diazinon, dimefox, dimethoate, Dimite, ethion, fenthion, endosulfan, guthion, Kelthane, malathion, parathion, naled, ovex, sulfotepp, schradan, Sulphenone, TEPP, tetradifon, EPN, phorate, and Di-Syston. For proper dosages follow the directions of the manufacturer. Some possess residual toxicity, whereas others are primarily contact in action, requiring repeated applications. Control in greenhouses may be accomplished by spray, dust, or aerosol formulations of these chemicals.

The continuous use of one kind of miticide should be avoided to prevent the development of strains of mites resistant to that chemical. This is not entirely the solution to the problem because alternating miticides or using combinations of miticides have resulted in the development of resistance to the other miticides as well. Resistance to phosphate-type miticides has been solved, at least in some instances, by changing to another group of chemicals like Aramite, chlorobenzilate, or Kelthane. Further research is needed to completely solve the resistance problem.

References: *U.S.D.A. Bul.* 416, 1917; *Va. Agr. Exp. Sta. Tech. Bul.* 113, 1949; *J. Econ. Ent.*, 57:50–57, 1964.

CYCLAMEN MITE

Steneotarsonemus pallidus (Banks), Family Tarsonemidae

This mite is chiefly a pest of greenhouse plants, especially cyclamen gerbera, snapdragon, and African violets. At times it seriously injures garden plants such as delphinium, dahlia, and strawberry. Symptoms of their presence, caused by removal of plant sap, are distortion and stunting of flowers and foliage, with or without blackening of the areas fed upon. Attacks are confined primarily to the younger leaves.

Adult mites are amber- or caramel-colored; the younger stages are white (Fig. 262). They are too small to be seen without magnification. Tiny pearl-like eggs hatch in a week or more. The first instar larva has only three pairs of legs, subsequent instars, four pairs. Breeding is continuous in the greenhouse, and a generation may be completed in about three weeks; outdoors this may be greatly extended, depending on the temperature. Outside the greenhouse, the mites winter in the crowns of the host plants.

Considerable natural control results from predatory mites in the genus *Typhlodromus*. Sanitation measures should be practiced where infested plants are handled. Fumigation with methyl bromide, 2 pounds per 1000 cubic feet for two hours at 75° F., is an effective method of ridding plants of the mites if the plants are tolerant to this fumigant. Immersing house plants for fifteen minutes in water held at 110° F. controls the mite.

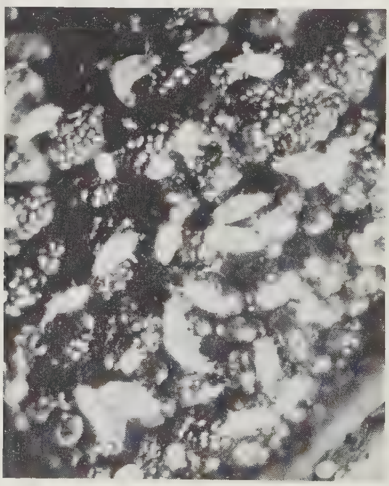


Fig. 262. Various stages of the cyclamen mite; greatly magnified. (U.S.D.A.)

Chemical sprays of endosulfan, endrin, Kelthane, and Telodrin have given effective mite kill. Strawberries should not be treated with any of these chemicals during the bearing season.

References: *J. Agr. Res.*, 10:373–390, 1917; *Calif. Agr. Exp. Sta. Bul.* 713, 1949; *J. Econ. Ent.*, 46:555–560, 707–708, 1953; 50:648–652, 1957; 56:565–571, 1963.

GREENHOUSE WHITEFLY

Trialeurodes vaporariorum (Westwood), Family Aleyrodidae

The greenhouse whitefly feeds in both the immature and the adult stages by sucking plant juices. Heavy feeding gives the infested leaves a mottled appearance or causes them to turn yellow and die. The sticky honeydew excreted by the insect often glazes the lower leaves and permits the development of black sooty mold on the surface, thus detracting from the beauty of the plants.

This insect is chiefly a pest in greenhouses, but at times it attacks outdoor plants such as tomato, potato, tobacco, strawberry, grapes, ageratum, aster, calendula, goldenglow, and lantana.

The adult is about $\frac{1}{16}$ inch long, has four wings which, along with the dorsal part of the body, are covered with a white waxy powder. The light green oval flattened nymphs are about the size of a small pinhead and are attached to the leaf surface until mature. Their bodies are covered with radiating long and short filamentous threads. They resemble young soft-scale insects. The length of the nymphal period is almost a month, the last instar being more elevated and slightly segmented. Emerging adults soon mate and begin depositing their elongated, yellow eggs, attaching them to the host by a short stalk. Before hatching the eggs darken. Several overlapping generations may develop each year in greenhouses or out-of-doors in the South. This species does not survive the winters in the North except in greenhouses.

Other species that are similar in appearance and habits are the azalea whitefly, *Pealius azaleae* (B. and M.); the avocado whitefly, *Trialeurodes floridensis* (Quaintance); the strawberry whitefly, *T. packardi* (Morrill); the grape whitefly, *T. vittata* (Quaintance); and the rhododendron whitefly, *Dialeurodes chittendeni* Laing.

For controlling whiteflies in commercial greenhouses, aerosols of endosulfan, malathion, parathion, or TEPP are recommended. Naled applied to the steam pipes in winter at the rate of 5 ounces of the emulsifiable concentrate per 50,000 cubic feet of space also gives satisfactory control. Whiteflies on house plants can be killed by dipping or spraying with lindane, malathion, or rotenone. Infested out-of-door plants can be treated by spraying with any of the aforementioned chemicals. Follow the recommendations of the manufacturer. For many years calcium cyanide fumi-

gation of greenhouses has been a standard control method. Dosages vary depending on the tightness of the house and the tolerance of the plants to this gas, but the minimum amount is 0.25 ounce of 50% commercial calcium cyanide to each 1000 cubic feet of area. The fumigation must be carried out in the evening under low-humidity conditions, and the house should be ventilated thoroughly before sunrise in order to avoid plant injury.

References: *U.S.D.A. Misc. Pub.* 626, 1948; *J. Econ. Ent.,* 41:624–631, 1948; *Calif. Agr. Exp. Sta. Bul.* 713, 1949.

THRIPS

Order Thysanoptera, Family Thripidae

Several species of thrips may seriously damage garden flowers and vegetable crops, the more common ones being flower thrips, *Frankliniella tritici* (Fitch); tobacco thrips, *F. fusca* (Hinds); bean thrips, *Caliothrips fasciatus* (Perg.); greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché); chrysanthemum thrips, *Thrips nigropilosus* Uzel; onion thrips, *T. tabaci* Lind.; gladiolus thrips, *Taeniothrips simplex* (Mor.); western flower thrips, *Frankliniella occidentalis* (Pergande); and iris thrips, *Iridothrips iridis* (Watson).

Plant injury is caused by both nymphs and adults rasping the bud, flower, and leaf tissues of the host plants and then sucking the exuding sap. This causes distorted and discolored flowers and buds, and gray or silvery speckled areas on the leaves. Gladiolus thrips also feed on the corms in storage, causing russeted areas and lowered vigor, which results in retarded growth and smaller flowers.

Adult thrips are generally less than 2 millimeters in length, usually tan-to-dark brown-bodied, with four featherlike wings (Fig. 240). Nymphs are creamy white and wingless. Eggs are deposited in the plant tissues, the young developing to maturity in approximately two or more weeks. The number of generations produced each year depends primarily on the species, the temperature, and other climatic factors. Most species produce many generations in a season. Females may lay fertilized or unfertilized eggs, the latter developing into males only.

Control for garden crops is accomplished by sprays or dusts of DDT, malathion, rotenone, diazinon, dimethoate, parathion, or toxaphene. Two or three applications at seven- to ten-day intervals is generally needed to control an infestation. Aerosols of these chemicals are commonly employed for thrips control in greenhouses. Migrating or wind-borne thrips can be prevented from entering greenhouses by installing cheesecloth coverings impregnated with emulsifiable dieldrin over the greenhouse vents.

References: *Calif. Cir.* 337, 1935; *Bul.* 609, 1937; *Fla. Agr. Exp. Sta. Bul.* 357, 1941; *U.S.D.A. Cir.* 445, 1937; *Can. Dept. Agr. Pub.* 69, 1952; *J. Econ. Ent.*, 57:357–360, 1964.

GARDEN WEBWORM

Loxostege similalis **(Guenée), Family Pyralidae**

The webworm is the larva of a small buff yellow moth with a wingspread of about an inch. The wings have both lighter and darker markings; their arrangement and the shape of the insect are illustrated in Fig. 263. The larval stage is a slender caterpillar, usually green in color but often varying to different shades of yellow, with black dots on each segment. It has the habit of spinning a silken thread wherever it crawls, and as a result there is considerable webbing of the plants on which it feeds.

Fig. 263. The garden webworm, *Loxostege similalis* (Guenée). (U.S.D.A.)

This species is a general feeder, devouring the foliage of both garden and field crops, especially beets, legumes, and cotton. Several weeds are also hosts, pigweed being the most common. The insect is widely distributed in the United States but is more of a pest in the Middle West and Southwest.

Development may continue throughout the year in the extreme South, whereas in the North the winter is passed as a pupa. Between these two areas overwintering as larvae also occurs. When moths appear in the spring, eggs are deposited in groups consisting of a few to almost fifty. On hatching, the larvae feed for three or more weeks, then construct silken-lined burrows on or in the soil in which pupation occurs. As many as five generations are produced in Texas, a reduced number in the more northern latitudes where the insect is found.

Harvesting infested hay crops checks this insect but migrating larvae often seriously damage adjacent garden or field crops. Chemicals that have given satisfactory control are DDT, Dylox, parathion, phosphamidon, and toxaphene. Both sprays and dusts are effective. The larvae are easier to kill in the early instars before much webbing has occurred. Selection

of the proper chemical will depend on the residues involved on a particular crop.

References: *U.S.D.A. Farmers' Bul.* 944, 1918; *J. Econ. Ent.*, 48:224, 1955.

GARDEN FLEAHOPPER

Halticus bracteatus **(Say), Family Miridae**

Fleahoppers, probably American in origin, are found from Maine to Florida and west through the central states to Utah. The appearance of the insects, except for size, is shown in Fig. 264, which presents a winged male and short-winged female. Long-winged females also occur, and resemble the males. The large hind legs enable them to hop actively. Maximum length of the winged forms is about $\frac{1}{10}$ inch.

Fleahoppers hibernate as adults. The number of generations produced varies in different latitudes, five being recorded for some southern states. Feeding is accomplished by sucking plant sap, which makes small discolored areas on the foliage. These areas often become numerous enough to cover leaves completely and to cause their death, injuring the plant seriously. Clover, cowpeas, alfalfa, many weeds, and garden crops are attacked by fleahoppers. Natural enemies have been observed but are said to have little effect on the population of the hoppers. Climatic factors probably keep them under control in the North.

Fig. 264. The garden fleahopper, *Halticus bracteatus* (Say): (left) male; (right) short-winged female. The long-winged female resembles the male. (Beyer, U.S.D.A.)

Suggested chemical control measures are the application of DDT, malathion, or rotenone. Either spray or dust formulations may be used.

References: *Va. Agr. Exp. Sta. Tech. Bul.* 101, 1946; 107, 1947; *J. Econ. Ent.*, 40:675–679, 1947; *U.S.D.A. Agr. Handbook* 290, 1965.

SEED CORN MAGGOT

Hylemya platura (Meigen), Family Anthomyiidae

Supposedly of European origin, the seed corn maggot has been known in this country for many years and is widely distributed in both the United States and southern Canada.

The sprouting seeds of several vegetable crops are attacked by this white maggot, resulting in weakened plants and poor stands. It occasionally injures sprouting corn but is much more likely to damage beans and peas. Cabbage, turnip, radish, onion, beet, spinach, and sprouting potatoes are other plants which may be attacked. Cool wet periods favor the development of the maggots.

The adult is a small fly, not more than $\frac{1}{5}$ inch long (Fig. 265). It is a near relative of several other root-infesting maggots which attack vegetable crops. Since the adult appears in early spring, it is thought that the puparium in the soil is the overwintering stage, but this has not been definitely determined. All life stages have been found during the winter in North and South Carolina. Eggs are laid in moist soil where there is an abundance of decaying vegetation. Newly hatched larvae may feed as scavengers, but they eventually crawl to the roots of plants and com-

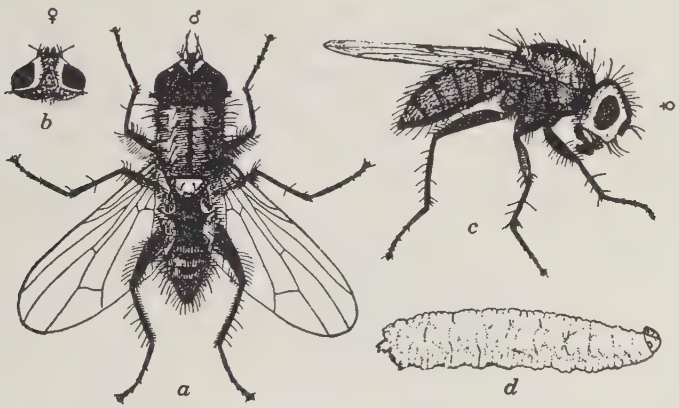


Fig. 265. The seed corn maggot, *Hylemya platura* (Meigen): *a,* adult male; *b,* head of female; *c,* side view of female; *d,* larva or maggot. (U.S.D.A.)

plete their feeding in two or three weeks. Pupation occurs in the soil and in a week or more the new adults emerge and repeat the cycle. Injury by later generations is usually of less importance.

Damage may be prevented by delaying planting until the maggots of the first generation have become fully grown and are changing to puparia. This date varies with the locality but is approximately June 10 for the state of New York. Avoid organic fertilizer in the seeded row, if possible. Thorough incorporation of organic matter in the soil, preparation of the surface layers of the soil for rapid germination, and shallow planting reduce damage since the insect is attracted by humus and moisture.

For protection of early planted seeds it is best to treat them with one of the commercial seed protectants according to label directions. Seeds can also be treated by the grower by mixing $\frac{1}{4}$ to $\frac{3}{4}$ ounce of dieldrin, heptachlor, or lindane with 100 pounds of seed. Wettable powder formulations containing 50% actual insecticide are recommended for seed treating. Diazinon has been approved for application in the transplant water of tobacco.

References: *U.S.D.A. Tech. Bul.* 723, 1940; *Leaflet* 370, 1962; *J. Econ. Ent.*, 51:704–707, 1958.

WHITE-FRINGED BEETLES

Order Coleoptera, Family Curculionidae

Originally from South America and discovered in Okaloosa County, Florida, in 1936, these beetles were later in the same year collected in Alabama and in other localities of Florida. Since that time they have been found in Mississippi, Louisiana, Georgia, North Carolina, South Carolina, and Tennessee. By the end of 1949, three species of white-fringed beetles were described as occurring in the United States: *Graphognathus leucoloma* (Boheman), *G. minor* (Buch.), and *G. peregrinus* (Buch.). *G. leucoloma* is represented by five races: *dubious, pilosis, imitator, striatus,* and *fecundis.* Information on the life history and habits of the original infestation, which consisted of *G. leucoloma fecundis,* is presented here.

The larvae and adults have been observed to feed on 385 species of plants, of which cotton, peanuts, okra, velvetbeans, soybeans, cowpeas, sweet potato, beans, and peas comprise the most important garden and field crops commonly attacked. Damage is done to the roots of the food plants by the larvae, and to the foliage and other plant parts by the adults.

The adult is a large, dark gray snout beetle, just under $\frac{1}{2}$ inch in length, with a lighter band along the outer wing margins (Fig. 266). All the beetles are females, incapable of flight and reproducing parthenogenetically. The legless white larvae are typical of the weevils.

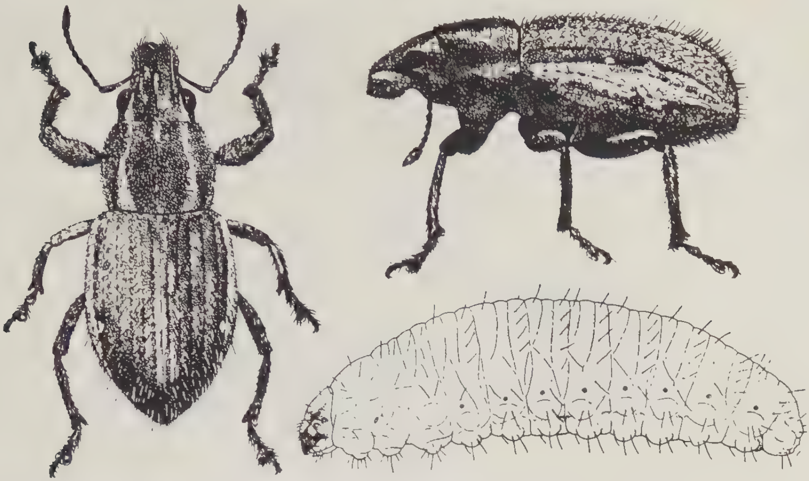


Fig. 266. The white-fringed beetle, *Graphognathus leucoloma* (Boheman). (U.S.D.A.)

Winter is usually passed as larvae in the soil, but the egg stage may also survive in well-protected situations such as haystacks or among unshelled peanuts. The first adults generally appear in May, and emergence continues into August in most latitudes. Egg-laying begins in five to twenty-five days and continues for thirty to sixty days. Masses containing up to sixty or more white eggs are most often deposited on plants or other objects at or near the point of contact with the soil. Hatching occurs in about seventeen days in midsummer, and the larvae feed in the soil until the following spring when they pupate and transform to adults. There is only one generation per year, but some larvae from eggs deposited late in the year do not reach maturity until the second summer.

Quarantines have been established to prevent the movement of soil or plant materials likely to be infested, since spread from one locality to another takes place primarily in this manner. Fumigation of such plant materials is a recommended procedure.

Cultural control practices suppress white-fringed beetle populations. These consist of planting oats or other small grains on the heavily infested portion of the farm and following a rotation in which peanuts, soybeans, velvetbeans, and other summer legumes are only planted in those areas once every three or four years. Treating infested soil with heptachlor, aldrin, dieldrin, chlordane, or DDT has given good control of the larvae. Dusts, wettable powders, emulsions, and granular formulations, or insecticide-fertilizer mixtures are suggested. Apply the insecticide over the soil surface and thoroughly mix it with the upper 3 or

4 inches by means of a disk harrow or similar device. Adults feeding on flowers or shrubs may be controlled by dust applications of undiluted cryolite or 5% DDT at the rate of 20 pounds per acre. Sprays are also effective when either 2 pounds of 50% DDT wettable powder or 10 pounds of cryolite per 100 gallons of water are used at ten- to fifteen-day intervals.

References: *U.S.D.A. Cir.* 850, 1950; *Leaflet* 401, 1962; *J. Econ. Ent.*, 45:457–461, 1952.

JAPANESE BEETLE

Popillia japonica **Newman, Family Scarabaeidae**

The Japanese beetle was first observed in this country about the year 1916 in Riverton, New Jersey. Since that time its continuous range has been extended, and it has become established in many isolated colonies from the Carolinas to Missouri northward. The larvae feed in the soil, devouring the roots of a large number of plants. They have been especially injurious to turf in lawns, parks, golf courses, and pastures, and are sometimes troublesome in nurseries and gardens. Adults feed on foliage, flowers (Fig. 267), and fruits during their period of activity, which is only on warm sunny days. Many woody plants, including fruit and shade

Fig. 267. Japanese beetle, and injury to a rose. (Ohio Agr. Exp. Sta.)

Fig. 268. Japanese beetle larvae.

trees, ornamental shrubs, flowers, small fruits, and garden crops are often severely damaged. Although the larvae have a broad tolerance range to soil *p*H, female beetles lay more eggs in soils of high acidity, the optimum being *p*H 4.5 downward. Heavily infested areas are in soils that have *p*H values of 5.3 or less.

The beetles are somewhat less than $\frac{1}{2}$ inch in length, shiny metallic green with coppery brown elytra. There are six tufts of white hairs on each side of the abdomen near the distal margins of the wing covers. Larvae resemble white grubs (Fig. 268), and the layman cannot be certain, usually, whether they are Japanese beetle larvae or young white grubs (see Fig. 271).

The winter is spent in the soil in the partly grown larval stage. In the spring they migrate near the soil surface and feed. By late May or early June pupation begins, and adults make their appearance in late June and continue activity until September. White eggs are laid in the soil at a depth of an inch or more and hatching takes place in about two weeks, the young larvae feeding until cold weather. There is only one generation per year. The complete life cycle is illustrated (Fig. 269).

Quarantines are maintained to restrict the movement of this insect, but they can be expected only to delay the spread rather than to prevent it. Trapping the adult beetles in yellow traps, baited with nine parts of anethol and one part of eugenol, has resulted in the capture of many beetles, but it does not prevent damage to plants. Biological control involves the use of parasites, predators, and disease organisms and is of some value. Two imported parasitic wasps, *Tiphia vernalis* Roh. and *Tiphia popilliavora* Roh., which attack the larval stages, and a parasitic

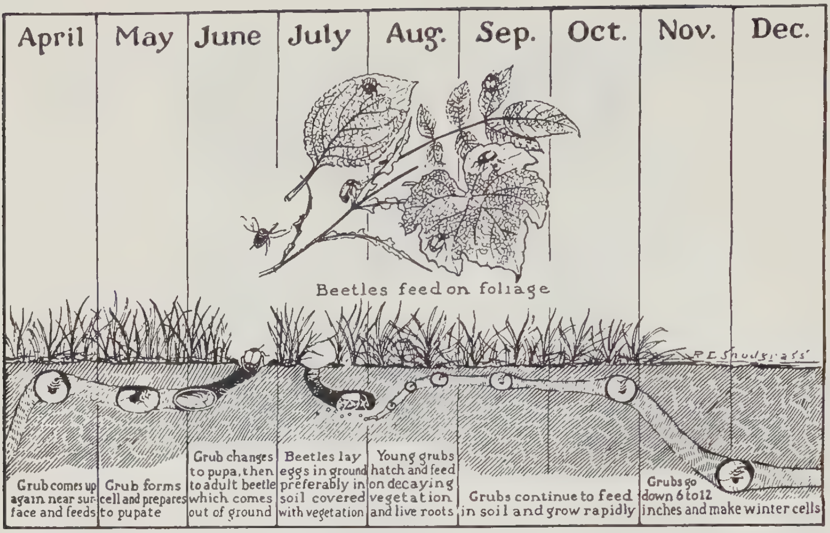


Fig. 269. Diagrammatic representation of the life cycle of the Japanese beetle in New Jersey. (Safro, N. J. Dept. of Agr.)

fly, *Hyperecteina cinerea* (Perris), which attacks the adults, have been introduced into the heavily infested areas. A bacterial disease, *Bacillus popillae* Dutky, commonly known as milky disease of the larvae, has caused marked reductions of the insects in some of the older infested areas. Moles, skunks, and birds also consume a large number of grubs.

For immediate effective control insecticides are necessary. To kill adults, apply carbaryl, DDT, malathion, methoxychlor, parathion or rotenone to the plants attacked. Persistent poisonous residues on edible crops can be avoided by selecting rotenone, carbaryl, or malathion as the insecticides.

It is well to direct control efforts toward killing the grubs in the soil by treating infested areas any time of the year except when the soil is frozen. Recommended chemicals and dosages per acre are: aldrin, heptachlor, and dieldrin, 2 to 3 pounds; chlordane, 5 to 10 pounds; toxaphene and DDT, 25 pounds. Watering the treated area soon after the application washes the toxicant into the soil where the grubs are feeding, if treatment is made during the summer months. The speed of insecticidal action depends on the temperature of the soil—the warmer the soil the faster the action. Milky disease spores are also available and should be applied to turf according to label directions.

References: *Conn. Agr. Exp. Sta. Cir.* 184, 1953; *U.S.D.A. Farmers' Bul.* 2151, 1960; *Leaflet* 500, 1961; *Agr. Handbook* 236, 1963; *Home and Garden Bul.* 53, 1964.

EUROPEAN CHAFER

Amphimallon majalis (Raz.), Family Scarabaeidae

The European chafer was discovered in Wayne County, New York, in 1940. By 1958 it had become established in nine counties in western New York state, and in 1959 it was found infesting a large part of Brooklyn and the New York harbor area. Isolated infestations occur in Connecticut, New Jersey, West Virginia, and Ohio.

The root-feeding grubs damage and sometimes destroy meadows, pastures, lawns, winter grains, and legumes.

Adults, resembling May beetles, are about $\frac{1}{2}$ inch long and light brown in color. They are most abundant from mid-June to mid-July. Mating flights occur about sunset when thousands of these insects swarm around trees, shrubs, and light poles. In about half an hour they settle on objects and mate. Then the females burrow into the soil 2 to 6 inches deep, lay their white eggs, and die soon afterwards. The beetles are harmless to plants or man.

Hatching occurs in two to three weeks, and the white curved larvae (see Fig. 271) with brown heads attain maximum growth in approximately three and one-half months. They burrow below the frost line in the fall and return near the surface of the soil in the spring. After feeding a short period most larvae change to pupae and emerge as adults. Some spend a second summer in the soil and pupate the following spring. The life cycle usually is completed in one year, but occasionally requires two years.

Infested areas are under Federal and State quarantines designed to prevent interstate spread of the insect. Natural enemies include poultry, birds, skunks, moles, shrews, and some predaceous beetles.

Application of chlordane, dieldrin, or heptachlor to grub-infested soil at the dosages recommended for larvae of Japanese beetles will control this pest.

Reference: *U.S.D.A.* PA-455, 1961.

ASIATIC GARDEN BEETLE

Maladera castanea (Arrow), Family Scarabaeidae

First reported from New Jersey in 1921, this beetle has now spread to other localities of the Atlantic coastal states, from Massachusetts to South Carolina, and westward to Ohio. Damage is caused by the larvae or grubs feeding primarily on the roots of grasses and, to a lesser extent, on garden vegetables and flowers, and by the adults devouring the foliage and flowers of both woody and herbaceous plants. The adults are active only at night, especially when the air temperatures are rather high. They

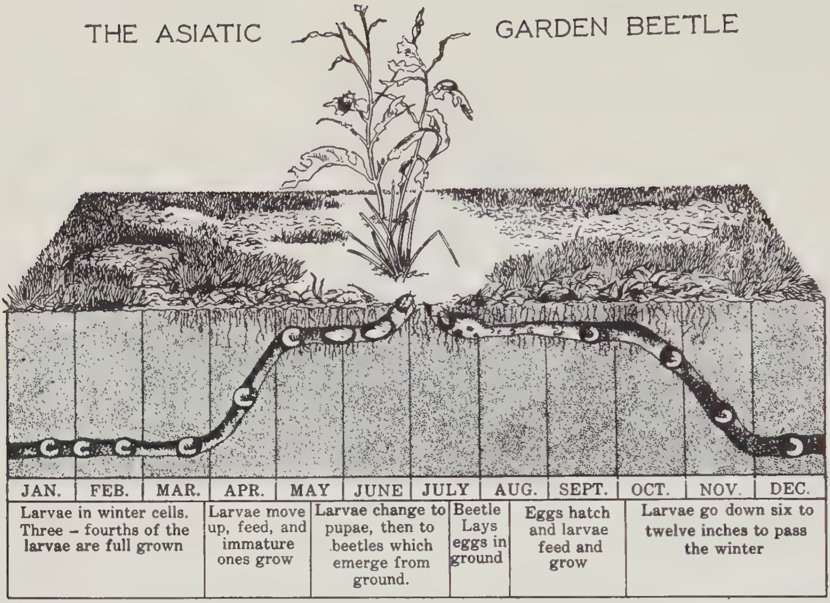


Fig. 270. Diagrammatic representation of the life cycle of the Asiatic garden beetle. (U.S.D.A.)

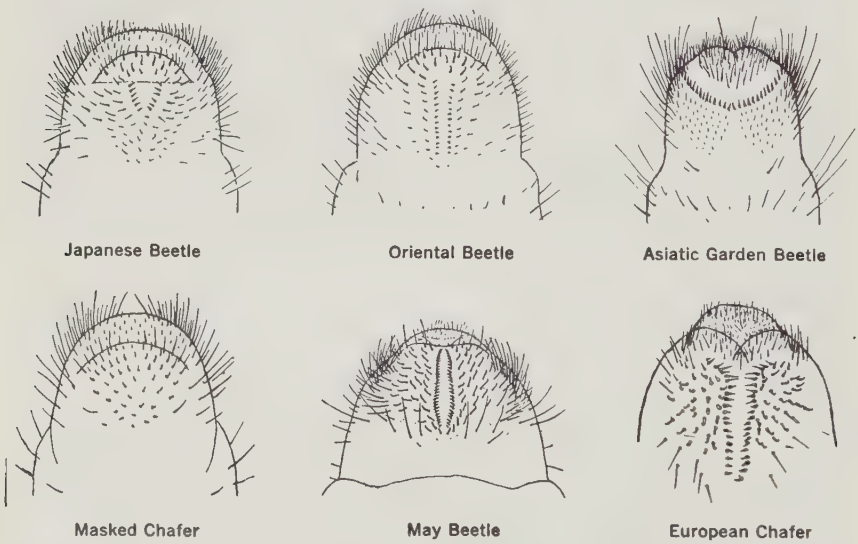


Fig. 271. Ventral view of last abdominal segment (raster) of common grubs showing rastrel pattern, useful in species determination. (Courtesy of U.S.D.A. and Cornell Univ.)

are attracted to lights and may become a nuisance when populations are high.

Overwintering larvae deep in the soil become active in the spring, migrate near the surface and feed. Pupation begins in late May, and velvety brown adults nearly $\frac{1}{2}$ inch in length appear in late June or early July. Eggs are laid principally in grassy areas, and the white curved larvae feed until cold weather, then migrate downward in the soil where the winter is passed. Only one generation develops each year. The complete life cycle is shown in Fig. 270. For larval identification, see Fig. 271.

Chemical control measures are directed toward killing the adults and larvae in the same manner as described for Japanese beetles (see p. 320).

References: *U.S.D.A. Cir.* 246, 1936; *Conn. Agr. Exp. Sta. Cir.* 184, 1953.

ORIENTAL BEETLE

Anomala orientalis Waterhouse, Family Scarabaeidae

So far as is known this insect was imported into Connecticut from Japan in 1920, and has now spread into several of the other eastern coastal states. Major injury is caused by the larvae feeding on the roots of plants, especially grasses; serious damage to lawns often results. Adult feeding on the foliage and flowers of plants is considered unimportant. The oriental beetle (Fig. 272) has also been a serious pest of sugarcane in Hawaii.

Partly grown white curved larvae with brown heads (Fig. 273) hibernate deep in the soil, coming near the surface in the spring and feeding until fully grown. Pupation takes place in early June, and new adults begin to appear in early July, continuing into August. They are $\frac{1}{2}$ inch or more in length and colored as illustrated (Fig. 272). Eggs are laid in the soil, and the newly hatched larvae feed and develop until cold weather, then

Fig. 272. The oriental beetle, *Anomala orientalis* Waterhouse. (Conn. Agr. Exp. Sta.)

burrow down to a depth of almost 1 foot where they pass the winter. Only one generation occurs each year (see Fig. 271 for larval identification).

Populations of this insect often occur in the same areas with the Japanese beetle and the Asiatic garden beetle. Experimental results show that the same insecticides for controlling these insects will control the oriental beetle (p. 320).

References: *Conn. Agr. Exp. Sta. Bul.* 304, 1929; *J. Econ. Ent.*, 41:905–912, 1948; 42: 366–371, 1949; *U.S.D.A. Home and Garden Bul.* 53, 1964.

NORTHERN MASKED CHAFER

Cyclocephala borealis Arrow, Family Scarabaeidae

This annual white grub is found over most of the United States as far south as Alabama. It is especially injurious to the turf of golf courses and lawns, the larvae burrowing through the soil and eating off the roots. Injury becomes more conspicuous after an invasion of moles, skunks, and birds, which tear up the loosened turf to feed on the grubs.

The adult is nearly ½ inch long, chestnut brown, and covered with fine hairs. Larvae are curved, white with brown heads, resembling small white grubs (see Fig. 271).

Winter is passed as larvae in the soil at a depth of about 16 inches. In the spring they migrate upward and feed until about June 1, then move down to an average depth of 6 inches, transform to pupae, and begin emerging as adults nearly two weeks later. In Ohio, most adults

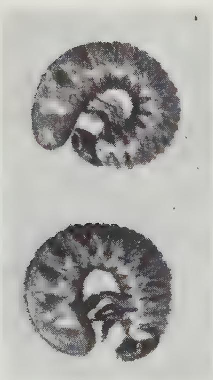


Fig. 273. Larvae of the oriental beetle. (Friend, Conn. Agr. Exp. Sta.)

Fig. 274. A blister beetle, *Epicauta pestifera* Werner, common in gardens and clovers.

are present from June 25 to July 25. They are nocturnal, usually emerging about dusk, and are active during early evening hours. No food is taken since their mouthparts are nonfunctional. Oviposition begins a few days after emergence, and the white eggs are placed 4 to 6 inches below the soil surface. Hatching occurs in three weeks; the larvae feed until cold weather, then migrate downward in the soil. One generation occurs each year.

A related species, with similar habits and life cycle, is the southern masked chafer, *C. immaculata* (Oliv.).

Experiments indicate that these insects can be readily controlled by soil insecticides at the same dosages indicated for Japanese beetle (p. 320).

References: *J. Agr. Research*, 62:79–86, 1941; *J. Econ. Ent.*, 31:340–344, 1938; 42:626–628, 1949; 45:347–348, 1952; *U.S.D.A. Home and Garden Bul.* 53, 1964.

BLISTER BEETLES

Order Coleoptera, Family Meloidae

Many species in the family Meloidae are injurious to plants. Some of the most common are the margined blister beetle, *Epicauta pestifera* Werner (Fig. 274), the striped blister beetle, *E. vittata* (F.), the black blister beetle, *E. pennsylvanica* (DeG.), the spotted blister beetle, *E. maculata* (Say), the clematis blister beetle, *E. cinerea* (Först.), and the ash gray blister beetle, *E. fabricii* (LeC.). Among crop plants alfalfa suffers much damage at times; sugar beets may be destroyed; garden vegetables in wide variety and many flowers and other ornamentals are often seriously injured. Some blister beetles are known as "old-fashioned potato beetles" when they feed on that host. The larvae are beneficial since they feed on grasshopper egg masses. Adults of the several species have similar habits. They appear when summer is well advanced, the entire population emerging in a very short period and likely to do much damage before they are noticed. They feed on the foliage, usually in large numbers, and after defoliating a plant will migrate to others.

Several insecticides readily control blister beetles. Recommended materials are carbaryl, cryolite, DDT, naled, endosulfan, methoxychlor, parathion, and toxaphene. Follow the directions on the package label. Direct the application to the adult beetles.

MOLE CRICKETS

Order Orthoptera, Family Gryllidae

Outbreaks of these insects have occurred at various times and places in the South Atlantic and Gulf Coast states from North Carolina to Texas. Garden vegetables, tobacco, peanuts, strawberries, and grasses are often

Fig. 275. The changa, *Scapteriscus vicinus* Scudder.

Fig. 276. The northern mole cricket, *Gryllotalpa hexadactyla* Perty, and its injury to potato.

damaged by the nymphs and adults that feed underground, at or near the soil surface. They chew the roots, tubers, and underground stems, and also attack strawberries and other fruits that touch the ground.

Four kinds of mole crickets occur in the infested area mentioned. The most common and abundant species is the southern mole cricket, *Scapteriscus acletus* R. and H., which in some localities is accompanied by the changa or Puerto Rican mole cricket, *S. vicinus* Scudder (Fig. 275). These two species are most often found in sandy soils. The short-winged mole cricket, *S. abbreviatus* Scudder, is found only in the southern third of Florida, and the northern mole cricket, *Gryllotalpa hexadactyla* Perty (Fig. 276), is rather scarce except in a few localities with wet heavy soils.

All species closely resemble each other except for size. Fully grown mole crickets are $1\frac{1}{2}$ inches long, brown in color, with bead-like eyes, and short, stout front legs fitted for digging. Winter is passed as nymphs or adults in the soil, migration downward occurring during cold weather. In the spring and early summer the eggs are laid in cells constructed in the soil by the female. Ordinarily about thirty-five eggs are placed in each cell. Hatching occurs in ten to forty days depending on the prevailing temperatures. The young crickets grow rapidly during the summer and early fall, most of the species becoming adults before midwinter. Only one generation occurs each year. If the soil is flooded, mole crickets leave their burrows and swim about in an effort to locate dry land.

Chlordane at $1\frac{1}{2}$ to 2 pounds per acre is widely recommended as a

broadcast application for mole cricket control on vegetables and other crops. Since mole crickets feed at or near the soil surface, mixing the insecticide with the upper few inches increases its effectiveness. Aldrin, dieldrin, and heptachlor have been recommended for controlling infestations in grass at the dosage of 2 to 3 pounds per acre.

Poisoned baits can also be used. For best results scatter the bait late in the evening in early August and September when the nymphs are growing fast and require more food. Prepare the bait by mixing 100 pounds of mill-run wheat bran, 8 pounds of sodium fluosilicate, or 50% chlordane wettable powder with 3 to 5 gallons of water. Mix the poison and bran thoroughly, then add enough water to cause the bait to form a ball of loose texture when squeezed in the gloved hand. Moistened bait will mold so only enough for a single application should be mixed at one time. This quantity will treat about 5 acres. A single application usually kills about three-fourths of the mole crickets in a given area, since they do not all feed at the same time and others may migrate from adjacent areas. Therefore a second and sometimes a third or fourth application may be needed at ten-day intervals. Increased effectiveness can be expected when recently plowed and disk-harrowed fields are baited, dusted, or sprayed after a good rain or irrigation. All these chemicals are poisonous and care must be exercised in their use.

Reference: *U.S.D.A. Leaflet* 237, 1953.

SERPENTINE LEAF MINER

Liriomyza brassicae (Riley), Family Agromyzidae

The serpentine leaf miner causes damage in the larval stage by mining between the upper and lower surfaces of the leaves of many plants in America and Europe. These mines are light in color, narrow, and winding. Besides rendering edible portions of vegetable crops unsalable, the leaf miner interferes with the normal photosynthesis of the plant. This insect is more prevalent in the warmer areas of the country.

Shiny black flies with yellow markings deposit pale white oval eggs into plant tissues. Inserted from the bottom of the leaf, the eggs are placed against the upper epidermis. The average hatching period is four days; the white to pale yellow larvae with black mouthparts mine the leaves for about five days in the summer months, but for longer periods when temperatures are lower. Normally the larvae change into shiny brown puparia in the soil, but in arid and semi-arid areas they have been observed changing to this stage in the leaf mines. In about ten days the flies, 1 to 1.75 millimeters in length, emerge and start the cycle anew. The average period for the entire life cycle is twenty-three days, and several overlapping generations occur each year. In the northern areas of

distribution, overwintering is in the puparium stage. Other species of leaf miners cause similar damage and have similar life cycles.

Many natural enemies attack this pest. Some parasites of importance are *Solenotus begini* (Ashmead), *S. websteri* (Crawford), *Derostenus pictipes* Crawford, *Chrysocharis ainsliei* Crawford, and *C. parksi* Crawford.

Sprays or dusts containing diazinon, parathion, guthion, or Dylox have given satisfactory control. Emulsifiable formulations are generally more effective. Consideration must be given to the possibility of poisonous residues when selecting the insecticide for protecting a particular crop.

References: *J. Agr. Res.*, 1:59–88, 1913; *Fla. Agr. Exp. Sta. Press Bul.* 639, 1947; *J. Econ. Ent.*, 51:357–359, 1958.

MISCELLANEOUS PESTS

False Chinch Bug, *Nysius ericae* (Schill.), resembles the chinch bug for which it is often mistaken, but is slightly shorter and more slender. It is a pest of beets, potatoes, cabbage, and other crucifers and is sometimes found on grape, corn and sorghums. It is one of the more important sugar-beet pests. Although widely distributed in the United States, it causes the most damage in the semiarid regions west of the Mississippi River. The bugs increase in numbers during the early spring and summer, chiefly among weeds and other uncultivated plants. When these plants become less succulent, migration to garden crops takes place, and the removal of sap by the piercing-sucking bugs causes the leaves to wilt and die.

The adults are about $\frac{1}{8}$ inch long, narrow-bodied, and gray-brown. Both nymphs and adults overwinter among plant remnants and become active early in the spring. Crescent-shaped pink eggs, laid in the soil and on foliage and flowers of low-growing plants, hatch in four days, and the red-brown nymphs feed for about three weeks before transforming to adults. There are four or five generations each year in the North.

It is probably cheaper to combat the occasional damaging population directly than to attempt prevention of such outbreaks. The insecticides recommended for chinch bugs are suggested for its control (p. 178), along with endosulfan, malathion, and parathion.

References: *U.S.D.A. Farmers' Bul.* 762, 1916; 2168, 1965; *J. Agr. Res.* 13:571–578, 1918.

Zebra Caterpillar, *Ceramica picta* (Harris), is velvety black with prominent yellow stripes, and reaches a length of 1.5 inches when fully grown. The moth lacks easily described markings but is of a general rusty brown color and has a wingspread of almost 2 inches. Eggs are laid in masses, and the hatching larvae devour the foliage of a wide variety of flowers and vegetable garden plants in mid and late summer. Cabbage and other

cruciferous plants are often damaged. Distribution of the insect is general. Dusts of 5% DDT, 50% cryolite, a 1-to-3 mixture of calcium arsenate and hydrated lime, or a 1-to-10 mixture of lead arsenate and hydrated lime, have given satisfactory control. Spot treatment is generally sufficient to eliminate the caterpillars. Any crop receiving a regular spray program is not damaged by this insect.

Vegetable Weevil, *Listroderes costirostris obliquus* (Klug), is a South American beetle that has been known in this country since 1922. It now occurs in the Gulf Coast states and in California, where it attacks potatoes, tomatoes, turnips, carrots, and many other vegetable crops, as well as

Fig. 277. The vegetable weevil, *Listroderes costirostris obliquus* (Klug). (U.S.D.A.)

weeds. Both larvae and adults feed, principally at night, on the buds, foliage, and roots of such vegetables as turnips and carrots. Stems of plants may be cut off at ground level, the injury resembling that of cutworms.

The adult weevil is about $\frac{3}{8}$ inch long, dull gray-brown with a pale gray mark near the posterior end of each wing cover, forming an inconspicuous V-shaped spot when the wings are at rest (Fig. 277). In common with most weevils, the adults have the habit of feigning death when disturbed. In the southern states they are active throughout the fall, winter, and spring, and estivate during the summer months. Some individuals live almost two years. Only female weevils are known; therefore reproduction is parthenogenetic. Oviposition begins in the autumn, and the eggs are placed on the plants or soil near-by. Hatching occurs after an incubation

period of two or more weeks and the pale green legless larvae begin feeding, becoming fully grown in twenty-three to forty-five days. Pupation takes place in the soil, and transformation to adults may occur over a period of a few days to two weeks depending on the temperature. Completion of the life cycle varies from a little over a month to nearly four months. There is only one generation per year.

To protect plants that are attacked by this insect, apply DDT, parathion, cryolite or rotenone. Cultivation during the fall and winter kills many insects while they are in the soil.

References: *Calif. Agr. Exp. Sta. Bul.* 546, 1932; *U.S.D.A. Cir.* 530, 1939; *Farmers' Bul.* 2168, 1965.

Pale-Striped Flea Beetle, *Systena blanda* Melsheimer, is one of the larger species. It is almost $\frac{1}{6}$ inch in length, brown-black with a median cream-colored stripe on each wing cover (Fig. 278). Corn, tomatoes, peas, beans, peanuts, oats, cotton, and strawberries are some of the many hosts on which it feeds.

The life cycle has not been definitely recorded, but adults appear in the spring and continue to be numerous until midsummer, some still being found during the remainder of the summer and in the fall. Larvae injure roots and seeds, and the adults eat small round holes in the leaves of food plants, typical of most flea beetles. Probably only one generation occurs each year.

Fig. 278. Adult and larva of the pale-striped flea beetle, *Systena blanda* Melsheimer. (U.S.D.A.)

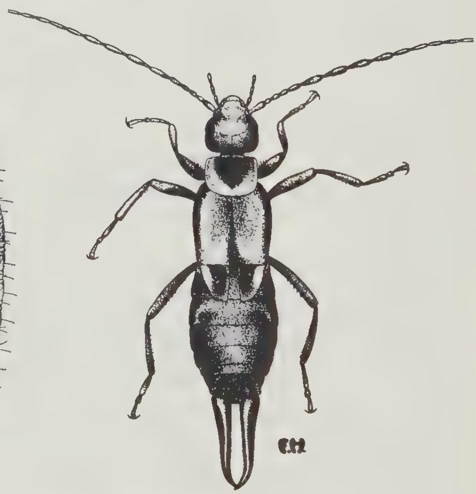


Fig. 279. A female European earwig; enlarged 4×. (Can. Dept. of Agr.)

A control measure practiced for most garden crops is the application of a dust containing 5% DDT or 0.75% rotenone at 20 to 30 pounds per acre. (See p. 289 for a description of other species of flea beetles and detailed control measures.)

European Earwig, *Forficula auricularia* L., a native of Europe, was first reported in Seattle, Washington, in 1907. It has since become a pest in many areas from the west to the east coast of the United States and southern Canada. The earwig is found in gardens where it eats flowers and foliage of many plants such as seedling vegetables, dahlias, carnations, chrysanthemums, lettuce, celery, marigolds, and potatoes. Another objection to this pest is its habit of entering houses.

The adults appear as shown in Fig. 279. This stage passes the winter in the soil. White eggs are laid in underground nests during January and February, hatching occurs in April and new adults appear in July. Some of these adults enter the soil, lay eggs, and produce a second generation by August.

Since earwigs seldom fly, a favorite control method is spreading granules or dusts of DDT, chlordane, malathion, or methoxychlor where they are apt to crawl. Make one or two applications in late spring about a week apart and treat the soil around the foundations of houses, along walks, fences, and around trees. The same insecticides are suggested for controlling this insect when found attacking plants. An additional chemical, carbaryl, is suggested for treating edible plants close to harvest.

References: *U.S.D.A. Tech. Bul.* 766, 1941; *Agr. Inf. Bul.* 237, 1962; *Can. Dept. Agr. Pub.* 21, 1953; *J. Econ. Ent.,* 56:29–31, 1963.

Slugs and Snails are distributed throughout the world, frequently causing damage to greenhouse and garden plants (Fig. 280). Some slugs are especially injurious in mushroom houses. Young seedlings and the more succulent parts of plants are devoured by these pests. They leave a trail of mucus on the surfaces on which they crawl, and, on drying, silvery marks result which are objectionable, especially on floral or ornamental plants. Only very humid environments favor the development of slugs and snails.

Thirty-two species of slugs have been recorded in the United States. Those of most importance as pests are the spotted garden slug, *Limax maximus* L. (Fig. 281), the tawny garden slug, *L. flavus* L., the greenhouse slug, *Milax gagates* (L.), and the gray garden slug, *Deroceras reticulatum* (Müller). All slugs are similar in general appearance but vary in coloration and length, depending on the species. The spotted garden slug may reach a length of 8 inches, whereas the true garden slug averages about 1 inch in length. Tawny slugs rarely attain a length of 4 inches.

Fig. 280. Garden slugs, and damage to beans. (U.S.D.A.)

Fig. 281. The spotted garden slug, *Limax maximus* L. About one-half natural size. (U.S.D.A.)

Only a few of the several hundred species of snails recorded for the United States are of importance as pests. These are the brown garden snail, *Helix aspersa* (Müller), the banded wood snail, *Cepaea nemoralis* (L.), the bush snail, *Zonitoides arboreus* Say, the white garden snail, *Theba pisana* (Müller), the subulina snail, *Subulina octona* (Brug.), and four species of cellar snails, *Oxychilus cellarius* (Müller), *draparnaldi* (Beck), *helveticus* (Blum), and *alliarius*, Müller. They are usually of some shade of gray, but their shells vary from nearly white through brown to black

Fig. 282. A fully grown snail; about natural size. (U.S.D.A.)

and are often ornamented with stripes or mottlings of contrasting colors (Fig. 282).

Slugs and snails pass the winter in sheltered situations out-of-doors in colder regions but continue activity throughout the year in greenhouses or in warmer regions. Snails seem to be more winter-hardy. Most slug species overwinter as eggs. Both animals deposit eggs in moist habitats with development to maturity requiring a year or more depending on the species. Common garden snails may survive in captivity for nine years.

These pests are controlled by poisoned baits containing metaldehyde plus either calcium arsenate or sodium fluosilicate. Baits are available commercially, or they may be prepared by mixing 1 ounce of metaldehyde, 2 ounces of calcium arsenate, or 1 ounce of sodium fluosilicate with 2 pounds of bran or corn meal. Moisten the bait with water before applying, and use 1 pound per 100 square feet of area. Good control of slugs has also been reported with 15% metaldehyde dust. Make two or three applications about ten days apart, and direct the dust to all the surfaces over which they may crawl. One pound per 1000 square feet is the suggested dosage. Zectran and guthion have been employed for snail control with varying degrees of success. Diazinon is recommended for slug control.

References: *Conn. Agr. Exp. Sta. Cir.* 203, 1958; *U.S.D.A. Farmers' Bul.* 1895, 1953; *Home and Garden Bul.* 46, 1963; *J. Econ. Ent.*, 54:152–156, 1961.

Garden Symphylan, *Scutigerella immaculata* (Newport), or centipede, is not a true insect but a near relative. It is generally distributed and feeds on the roots of many plants both in the field and in the greenhouse.

Adults are white narrow-bodied creatures, almost $\frac{3}{8}$ inch in length, with a pair of long antennae and twelve pairs of short legs (Fig. 283). Egg-laying begins in the spring and continues throughout the summer. Masses containing up to twenty eggs are deposited and hatching takes place in about ten days. The symphylans are fully developed in forty-five to sixty

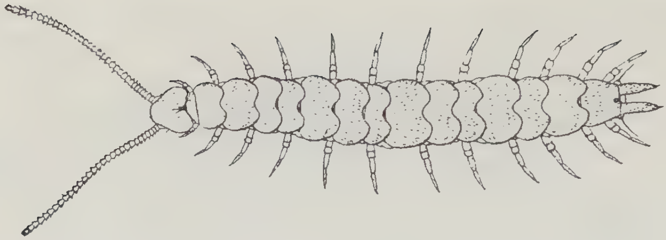


Fig. 283. Adult garden symphylan. (Drawing by A. E. Michelbacher.)

days, with all life stages occurring in the soil. During hot dry weather they migrate into the subsoil.

Where irrigation water is available, continuous submergence of fields for two weeks in the summer or one month in the winter will rid the soil of symphylans for two years. Fumigating soils with ethylene dibromide, Zinophos, methyl bromide, Nemacide, Telone, DD mixture, or carbon disulfide controls symphylans. Steam sterilization of the soil or treatment with 5 pounds of parathion per acre have also been employed with success. Drenching soils in benches with DDT or lindane has been a treatment in greenhouses.

References: *Ohio Agr. Exp. Sta. Bul.* 486, 1931; *Conn. Agr. Exp. Sta. Cir.* 203, 1958; *U.S.D.A. Agr. Handbook* 264, 1964; *J. Econ. Ent.*, 48:246–250, 1955; 52:666–683, 1959; 57:360–363, 525–527, 1964.

Millipedes eat the roots of various plants, including garden and greenhouse vegetables and flowers. They are usually abundant in moist soils high in organic matter. They resemble but can be distinguished from wireworms by their many body segments and numerous legs. Millipedes have two pairs of legs per segment except for the first six, which have only one pair per segment, and wireworms have three pairs of legs located on the three segments posterior to the head. Life cycles of millipedes have not been thoroughly studied. It is known that their eggs are laid on or in the soil, usually in clusters of twenty to one hundred. These hatch in about three weeks, and the young feed on decaying vegetable matter and grow rather slowly. Adult millipedes are said to overwinter in the soil and other secluded places that are moist. Control is accomplished by treating the soil with DDT, diazinon, malathion, or some of the other chemicals suggested for wireworm control (p. 142).

Nematodes of various species attack a wide variety of garden and greenhouse plants. Probably the most destructive species feed on the roots or tubers, causing stunting or development of knots or galls, an example being the root-knot nematodes. Some species are leaf or bud

feeders and are called foliar nematodes; still others are known as cyst nematodes, the soybean cyst nematode being an example. These pests are not insects but tiny roundworms. The root-knot species may complete their life cycle in one month. Control is difficult, but sanitation measures, crop rotation, fumigation, or steam sterilization of soils are the commonly recommended practices. Foliar nematodes are controlled by sprays of parathion at standard dosages.

Soil fumigation can be done at any time, but the treatment appears to be more effective in the fall when most nematodes are nearer the soil surface. Application of the fumigant and fall plowing can be combined into one operation, thus saving labor costs. Chemicals that have been used in nematode control are D-D mixture, Nemagon, ethylene dibromide, chloropicrin, Vapam, Nemacide, Telone, and Zinophos.

Reference: *U.S.D.A. Home and Garden Bul.* 46, 1963.

14

Insects Injurious to Cucurbit and Cruciferous Crops

STRIPED CUCUMBER BEETLE

Acalymma vittatum (Fabr.), FAMILY CHRYSOMELIDAE

This native insect is found from Mexico to Canada, primarily east of the Rockies. As soon as cucumber, squash, pumpkin, melons, and related plant seedlings push through the soil the beetles attack them, eating off the stems and cotyledons. If the plants survive, later feeding on the leaves, vines, and fruits by adults, along with larval mining of the roots, is often serious. In addition, the beetles are vectors of the organisms causing bacterial wilt and mosaic. Infection by these disease organisms is often more damaging than the insects.

The cucumber beetle is $\frac{1}{4}$ inch in length, yellow-green, with three black, longitudinal stripes (Fig. 284). This stage passes the winter in the shelter of plant remnants, becomes active early in the spring, and feeds on the

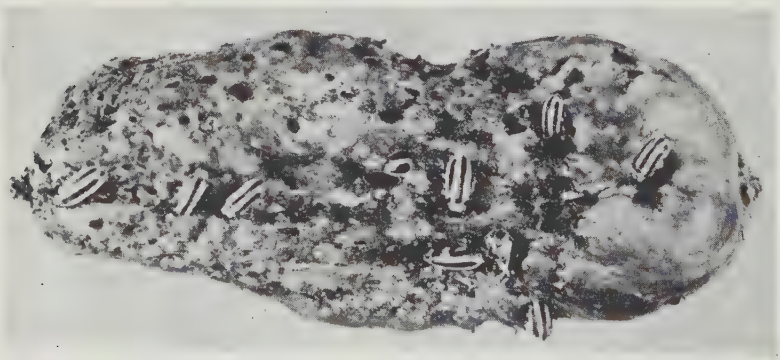


Fig. 284. The cucumber beetle, *Acalymma vittatum* (Fabr.), working on a cucumber. (Ohio Agr. Exp. Sta.)

blossoms and leaves of many other cultivated or wild plants. When favored host plants appear, migration to these areas takes place. Pale orange-yellow eggs are placed in the soil near the base of the plants. In about ten days hatching occurs, and the slender white larvae, darker at both ends, with three pairs of short legs, reach a length of almost $\frac{3}{8}$ inch in three or more weeks, then pupate in the soil, and ten days later emerge as adults of the next generation. Only one generation is produced in the northern range of the insect; farther south there are two, and there may be even more in the Gulf states.

Parasitic enemies include a tachina fly, *Celatoria setosa* (Coq.), a braconid wasp, *Syrrhizus diabroticae* Gahan, and a nematode, *Howardula benigna* Cobb. Of the several predators, a soldier beetle, *Chauliognathus pennsylvanicus* DeGeer, is considered the most important.

Although mechanical barriers of screening material and the use of trap crops are of value in protecting plants, insecticides are necessary. Applications should be made early and repeated at weekly intervals or after each rain in order to kill all beetles carrying the bacterial wilt organisms. There is no control for the disease once infection has set in.

Dusts or sprays of rotenone, purified DDT, carbaryl, endosulfan, malathion, parathion, diazinon, methoxychlor, or cryolite have been effective control chemicals. Insecticides are generally combined with a recommended fungicide. When edible plant parts are present, use only the insecticides recommended for your area.

References: *Ohio Agr. Exp. Sta. Bul.* 388, 1925; *Ext. Bul.* 459, 1966; *U.S.D.A. Agr. Handbook* 290, 1965.

OTHER CUCUMBER BEETLES

Order Coleoptera, Family Chrysomelidae

Other species of beetles attack cucumbers and related plants and cause the same type of injury. For the most part they have similar life cycles.

Spotted Cucumber Beetle (Fig. 285), *Diabrotica undecimpunctata howardi* Barber, feeds extensively on all cucurbits but is also a general feeder on many other plants. The larva of this species is known as the southern corn rootworm. Further discussion of this insect will be found under the heading "Corn Rootworms" (p. 184).

Western Spotted Cucumber Beetle, *Diabrotica undecimpunctata* Mann., is the common species west of the Rocky Mountains. Both larvae and adults attack cucurbits as well as several other species of plants.

Western Striped Cucumber Beetle, *Acalymma trivittatum* (Mann.), is also found in the West. It resembles the eastern species in appearance and habits, but it has a somewhat more general feeding range.

Fig. 285. The spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber. (Britton, Conn. Agr. Exp. Sta.)

Banded Cucumber Beetle, *Diabrotica balteata* LeC., is a southern species with rather general feeding habits.

Control measures suggested for the striped cucumber beetle are applicable for all these species.

SQUASH VINE BORER

Melittia cucurbitae (Harris), FAMILY AEGERIIDAE

The vine borer ranges from Canada to Argentina and is the most serious enemy of squashes in many places where they are grown commercially. It causes much trouble where only a few of them are grown in gardens. It rarely attacks cucumbers and melons, and great variation exists in the susceptibility of squash and pumpkin varieties. Hubbard squash is highly susceptible.

Damage is caused by the larvae tunnelling into the stems, often killing the plants, especially when they are working in the basal portions of the vines (Fig. 286). Sometimes the fruits are also attacked. Sudden wilting of a vine and the presence of sawdust-like excrement coming from holes in the stem are evidences of attack.

The adult is one of the moths known as "clear wings" because the hind wings are almost without scales. It is $1\frac{1}{2}$ inches in wing expanse, of metallic green-black color; the hind legs are fringed with black and orange hairs, and markings of similar color occur over much of the abdomen. The moths are day fliers and are often mistaken, as are other members

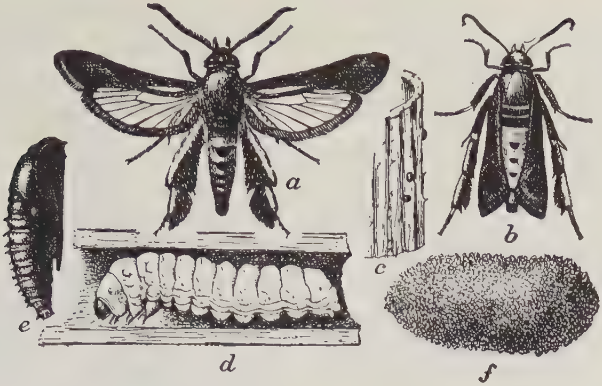


Fig. 286. The squash vine borer, *Melittia cucurbitae* (Harris): *a,* male moth; *b,* female with wings folded at rest; *c,* eggs shown on bit of stem; *d,* full-grown larva in vine; *e,* pupa; *f,* pupal cell; all one-third larger than natural size. (U.S.D.A.)

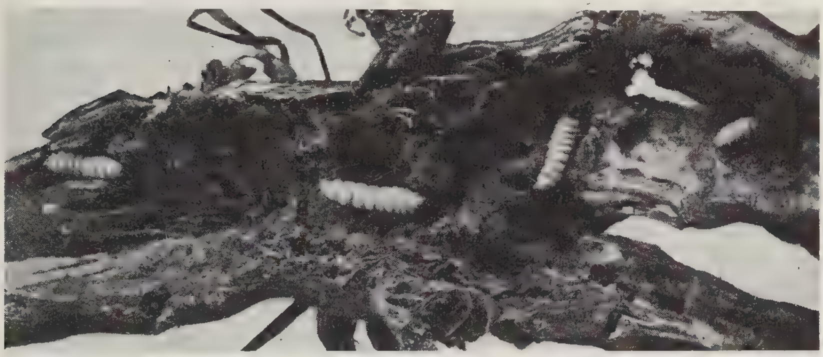


Fig. 287. Larvae of the squash vine borer shown at work in an opened vine. (Quaintance.)

of the group, for wasps. Larvae are white, heavy-bodied, and considerably over an inch in length when fully grown (Fig. 287).

The insect winters in the soil as a larva or pupa enclosed in a cocoon. Moths emerge in early summer and lay eggs on the stems of the plants, usually during April and May in the South, and June and July in the North. On hatching, the larvae bore into the vines and complete their development in four or more weeks, then leave the plant, crawl into the soil, spin a cocoon, and transform to pupae in areas where two generations develop. There is one generation in the North, two in the South, and a partial second in intermediate regions.

Control can be achieved by repeatedly treating the base of the plants with insecticides in order to kill the young larvae before they enter the vines. Begin treatment when the eggs appear (usually the last week in June for Ohio), and repeat five times at weekly intervals.

Recommended control chemicals are rotenone, purified DDT, methoxychlor, malathion, and parathion.

References: *Conn. Agr. Exp. Sta. Bul.* 328, 1931; *U.S.D.A. Home and Garden Bul.* 46, 1963; *Ohio Ext. Bul.* 459, 1966.

SQUASH BUG

Anasa tristis (DeGeer), Family Coreidae

The squash bug is well known and widely distributed in North America. Injury is caused by both nymphs and adults sucking the sap from the leaves and stems of squash and pumpkin, but related plants may also be attacked. This feeding causes wilting, and when severe the leaves become black and crisp.

The winged adult is gray-black and nearly an inch in length (Fig. 288). Only adult bugs live through the winter. They are found in all kinds of protected places, both out-of-doors and in buildings. Long before the cultivated food plants are to be found, the adults may be collected. What they feed upon in the interval between spring emergence and the time cucurbits are available has not been recorded. When the plants begin to develop runners, masses of orange-yellow to bronze-brown eggs, each containing almost a dozen or more, are deposited usually on the undersides of the leaves. Hatching occurs in about ten days or more, and the nymphs pass through five instars, requiring four to six weeks to reach maturity. Early instars are highly colored; the legs, antennae, and head are red and the abdomen green. A few hours after each molt the red parts become black. Later instars are of a dark greenish gray color. Because of the pro-

Fig. 288. The squash bug, *Anasa tristis* (DeGeer); adult, and different stages of nymphs.

Fig. 289. *Trichopoda pennipes* (Fabr.), a tachina fly with several hosts. Adult, and eggs attached to a squash bug. (U.S.D.A.)

tracted egg-laying period all stages are found throughout the summer. Only one generation develops each year.

Natural control may keep this insect from being a serious pest. Winter mortality is often high and parasitism of adults by the tachinid fly, *Trichopoda pennipes* (Fabr.), sometimes reaches 32% (Fig. 289).

If only a few vines are involved, the easiest control method is collection of the bugs and eggs by hand. Burying infested crop remnants by plowing after harvest reduces a population. When bugs appear in large plantings, application of insecticides is necessary. Recommended chemicals are purified DDT, parathion, malathion, sabadilla, carbaryl, rotenone, and pyrethrins. Observe the label precautions concerning residues.

Selecting varieties of squash resistant to the squash bug is a good practice. The following varieties are listed according to degree of resistance from high to low: Butternut, Royal Acorn, Sweet Cheese, Green Striped Cushaw, Pink Banana, and Black Zucchini.

References: *Conn. Agr. Exp. Sta. Bul.* 440, 1940; *Utah Agr. Ext. Cir.* 214, 1954; *J. Econ. Ent.*, 55:912–919, 1962; *Ohio Ext. Bul.* 459, 1966.

SQUASH BEETLE

Epilachna borealis **(Fabr.), Family Coccinellidae**

This is the second of the two plant-feeding lady beetles that attack crops in this country. All life stages resemble those of the Mexican bean beetle, except the markings of the adult which are apparent in the illustration (Fig. 290). The insect is generally distributed east of the Rocky Mountains but is comparatively rare as a pest. The common host plant is

squash. Adults hibernate during the winter, and two or three generations develop each season, the life cycle being essentially the same as that of the bean beetle. Sprays or dusts recommended for the bean beetle have given control of the squash beetle (p. 280).

Fig. 291. The melonworm, (left) *Diaphania hyalinata* (L.), and the pickleworm, (right) *D. nitidalis* (Stoll). (Quaintance.)

PICKLEWORM

Diaphania nitidalis (Stoll), Family Pyralidae

The pickleworm is injurious as far north as the central states only at comparatively rare intervals; in the South Atlantic and Gulf Coast states it is likely to be a serious pest every year. Summer squash is the favored host, but cucumber and muskmelons are also attacked. The larvae feed

on the blossom and vines, and mine into the developing fruits, usually the undersides, entirely ruining them for market purposes.

The moth has dark brown wing margins with central areas of light yellow and a wingspread of slightly more than 1 inch. The tip of the abdomen is tufted with hairs (Fig. 291). New adults emerge from the overwintering pupae and are active at night, laying tiny eggs in small clusters on the leaves, buds, vines, and fruits. Hatching occurs in a few days, and the black dotted light green larvae (Fig. 292) feed for nearly two weeks or more until fully grown, then pupate inside silken cocoons

Fig. 292. Pickleworms at work on a cucumber; below, a melonworm. (Quaintance and Smith.)

on the leaves. In five or more days the adults appear and lay eggs, which develop into the second generation. Two generations are often produced in its northern range, and five or more in the South. Activity is continuous through the winter in southern Florida.

Severe injury develops relatively late in the season; this may be avoided, to some extent, by early planting. Cucumbers and muskmelons can be protected by planting summer squash as a trap crop. Deep plowing to bury crop remnants containing pupae and other life stages reduces the infestation.

When the pickleworm first appears, which may be two weeks after a crop is seeded in some areas, start applying, at weekly intervals, one of the following insecticides: carbaryl, malathion, rotenone, or lindane.

References: *J. Econ. Ent.*, 41:334–335, 1948; 44:817–818, 1951; *U.S.D.A. Yearbook of Agriculture*, Plate 51, 1952; E–856, 1953; *Leaflet* 455, 1961; *Ohio Ext. Bul.* 459, 1966.

MELONWORM

Diaphania hyalinata (L.), Family Pyralidae

The light-colored areas in the wings of the moth of this species are of a pearly, iridescent whiteness, and the margins are velvety black. The arrangement of these colors is shown in Fig. 291. The moth is a day flier. Its habits are similar to those of the pickleworm, which it greatly resembles in the main features of its biology. The melonworm is not likely to occur as far north as the central states, but injury has been noted as far north as northern Kansas. The young larvae of the melonworm feed on foliage rather than blossoms; later they mine into the stems and the fruits. They are distinguished by the two dorsal white stripes along the length of the body (Fig. 292).

Control of this species is easier, owing to the foliage-feeding habits of the young larvae. They may be poisoned readily with the same insecticides recommended for the pickleworm.

MELON APHID

Aphis gossypii Glover, Family Aphididae

The melon aphid is widely distributed. It is more likely to injure melons and cucumbers, less frequently squashes and pumpkins. It has been recorded as feeding on 64 different plant species in Florida. Damage is caused by the nymphs and adults removing plant sap, which results in

Fig. 293. The melon aphid, *Aphis gossypii* Glover. (U.S.D.A.)

stunting of growth, curling of leaves, or death of the plant. In addition, this insect may transmit viruses causing mosaic diseases in plants, maize dwarf mosaic of corn is an example. The aphids vary from pale yellow to light or dark green, with black leg joints, cornicles, and eyes (Fig. 293). A more detailed description of this insect and its life cycle will be found under cotton aphid (p. 225), another common name for the melon aphid.

Natural enemies are numerous, the most common being lady beetles,

syrphid fly larvae, aphid lions, and the parasite, *Aphidius testaceipes* (Cresson).

Recommended insecticides are parathion, malathion, TEPP, demeton, diazinon, mevinphos, and endosulfan. If an infestation develops during the picking season, apply only TEPP or mevinphos to avoid the danger of poisonous residues. Making the application in the early morning or late evening is less hazardous to bees.

References: *Ohio Agr. Exp. Sta. Pub. Ser.* 11, 1964; *U.S.D.A. Agr. Handbook* 290, 1965; *Farmers' Bul.* 2148, 1960; *Leaflet* 389, 1964.

CABBAGE MAGGOT

Hylemya brassicae (Bouché), Family Anthomyiidae

The most destructive early-season pest of cabbage and cauliflower is the maggot. It is also a serious pest of radishes and often attacks broccoli, brussels sprouts, turnips, celery, and beets. Evident symptoms of infested cabbage and cauliflower are: the lower leaves become tinged with yellow,

Fig. 294. The cabbage maggot, *Hylemya brassicae* (Bouché); (right) adult, and, (left) larvae working in crown of plant. (Slingerland.)

and young plants fail to grow and may even wither and die. Injury results from the maggots feeding on the surface of the roots or tunnelling through them (Fig. 294). Fleshy parts of radishes and turnips become brown-streaked with these tunnels. This reduces their market value. Cool moist weather favors the development of this insect, and northern United States and southern Canada are the commonly infested areas of North America.

The winters are usually passed as brown puparia in the soil. Adult flies, slightly smaller than the house fly, begin emerging in April, and soon afterwards they lay white eggs at the bases of newly set plants or infest the plants while in the seed beds. Hatching occurs several days later, and the white tapered maggots feed on the roots, with development continuing for twenty to thirty days, after which transformation to puparia takes place in the surrounding soil. In a few more weeks emerging adult flies deposit eggs that develop into the second generation. Two to four generations occur annually, the number depending on the locality. Later generations injure late cabbage, turnips, and radishes.

Recommended chemical control measures consist of one or more of the following operations: surface application in a narrow band over the row immediately after transplanting in the field, adding insecticide to the transplant water, treating the furrow at the time of field seeding, or broadcast treatment before planting. Chemicals that have been effective are aldrin, chlordane, and heptachlor. When resistance to these chemicals develops, change to diazinon, guthion, or parathion. Much higher dosages are required for the broadcast treatment and in general the killing of maggots is not as good. Residue problems may arise from using these chemicals on radishes and turnips. Follow the detailed recommendations prepared for your area by the extension entomologist. An older, but still recommended control measure is to dust the base of new transplants of cabbage and related plants with a mixture of one part calomel and eight parts of an insecticidal diluent such as talc.

References: *N.Y. Agr. Exp. Sta. Cir.* 164, 1937; *Ohio Agr. Exp. Sta. Pub. Ser.* 11, 1964; *U.S.D.A. Home and Garden Bul.* 46, 1963; *J. Econ. Ent.*, 55:160–164, 1962; *Can. Dept. Agr. Pub.* 1027, 1957.

CABBAGE APHID

Brevicoryne brassicae **(L.), Family Aphididae**

Aphids on cabbage and related plants are often of this species; frequently turnip aphids are also found. The cabbage aphid is an imported species, presumably from Europe. The nymphs and adults remove plant sap, causing distortion, stunting, curling, wilting, and often death of the plants.

The aphid is a green species with a considerable amount of gray, waxy "bloom" on the surface, which gives heavily infested plants a whitish appearance. The winter is passed in the egg stage usually on remnants of the host plants, but in the South breeding may be continuous. Many generations may be produced in a season, over twenty-one having been recorded. Both winged and wingless individuals occur (Fig. 295), reproduction being parthenogenetic and ovoviviparous in warmer areas, with

males and oviparous females developing only in the fall in regions having cold winter weather. The life cycle is typical of most aphids.

Braconid parasites, especially *Aphidius testaceipes* (Cresson), are numerous and effective; their work is supplemented by the predatory attacks of many lady beetles, aphid lions, and syrphid fly larvae.

Fig. 295. The cabbage aphid, *Brevicoryne brassicae* (L.). (Knowlton, Utah, Agr. Exp. Sta.)

When chemical control is necessary, apply malathion, parathion, demeton, diazinon, guthion, mevinphos, naled, Di-Syston, and TEPP. TEPP and mevinphos have little residual action, and repeated applications may be necessary. These are the only materials recommended for checking an infestation that develops within a few days before harvest. For effective aphid control it is well to make applications before the leaves become cupped and distorted. Rotenone and pyrethrum emulsifiable sprays at manufacturer's directions are satisfactory for aphid control if they strike the aphids, but they have no residual effect. They may be applied with safety to control aphids near harvest.

References: *Ohio Agr. Exp. Sta. Pub. Ser.* 11, 1964; *U.S.D.A. Farmers' Bul.* 2148, 1960.

TURNIP APHID

Hyadaphis pseudobrassicae (Davis), Family Aphididae

This widely distributed species was not known to be distinct from the cabbage aphid until 1914. Its host plants, habits, and damage are similar to those of the cabbage aphid. The most serious damage from this pest occurs in the southern states where breeding may be continuous. Most damage to turnips occurs in late summer or fall.

Wingless turnip aphids are pale green and almost $\frac{1}{16}$ inch in length when fully grown (Fig. 296). Winged forms are pale green with black body markings and black heads. The biology is essentially similar to that of the cabbage aphid. In the Gulf states from fifteen to forty-five generations occur each year.

Fig. 296. The turnip aphid; wingless ovoviviparous female. (Paddock.)

This aphid is attacked by the same natural enemies and controlled by the same insecticides as given for the cabbage aphid (p. 346).

Reference: *U.S.D.A. Farmers' Bul.* 2148, 1960.

HARLEQUIN BUG

Murgantia histrionica (Hahn), Family Pentatomidae

The striking colors of this insect suggest its common name. Essentially southern in distribution, it is seldom injurious much farther north than 39° N . latitude. Favorite food plants are cole crops like cabbage, broccoli, turnip, horseradish, kale, and collards. Injury results when the nymphs and adults remove the plant sap causing wilting, distortion, and even death.

The shield-shaped black bugs with red, orange, or yellow markings, are nearly $\frac{3}{8}$ inch in length (Fig. 297). In its northern range the adult hibernates; in the Gulf states activity may continue all year. Highly ornamented keg-shaped eggs are laid in groups of about a dozen. These hatch in a week or more into nymphs, which feed for six to eight weeks, and, after passing through five instars, transform to adults. The number of generations depends on the climate, at least four being produced in the South, two being maximum north of Virginia.

Plowing under crop remnants, preferably after cold weather comes, is of value, and the benefits are increased if the practice is community-wide. Trap crops and hand-picking have also been practiced as control measures.

Good control has been obtained by applications of DDT, endosulfan, naled, malathion, or sabadilla, the last two being recommended for use

Fig. 297. The harlequin bug, *Murgantia histrionica* (Hahn); adult, and group of eggs. (U.S.D.A.)

Fig. 298. The imported cabbage butterfly, *Pieris rapae* (L.); (right) cabbage showing typical injury. (Pettit, Mich. Agr. Exp. Sta.)

near harvest. Rotenone is not an ideal insecticide to control this pest, but it can be applied near harvest without danger of poisonous residues.

References: *U.S.D.A. Farmers' Bul.* 1712, 1933; *Home and Garden Bul.* 46, 1963; *J. Econ. Ent.*, 41:808–809, 1948.

IMPORTED CABBAGE BUTTERFLY

Pieris rapae (L.), Family Pieridae

The cabbage butterfly is the adult stage of the imported cabbage worm, which is widely distributed over much of the world. Cabbage, cauliflower, broccoli, kale, mustard, and related plants, as well as nasturtiums and lettuce are common hosts. Damage is caused by the larvae devouring the leaves and sometimes boring into the heads of cabbage (Fig. 298). Related species, mostly southern in distribution, are the southern cabbage worm, *Pieris protodice* B. and L.; and the Gulf white cabbage worm, *Ascia monuste* (L.)(Fig. 299). All these species have life cycles similar to *P. rapae* (L.).

In the northern states the imported cabbage worm passes the winter in the chrysalis or pupal stage. White butterflies, tinged with yellow and having several black spots on the wings, emerge with the coming of warm

Fig. 299. The southern cabbage butterfly, *Pieris protodice* B. and L., above, and the Gulf white cabbage butterfly, *Ascia monuste* (L.), below.

Fig. 300. *Apanteles glomeratus* (L.), a parasite of the cabbage worm: *a*, adult; *b*, cocoon; *c*, adults escaping from cocoons natural size; *a*, *b*, highly magnified. (U.S.D.A.)

weather in early spring. They lay tiny yellow eggs, usually on the undersides of the leaves. These hatch in seven or more days into velvety green, pubescent caterpillars, each having a narrow orange stripe dorsally and paler broken stripes laterally. They have five pairs of prolegs. After feeding for about fifteen days they attain a length of almost $1\frac{1}{4}$ inches, then change to pupae on the plants or nearby objects, and in about ten days new adults emerge, completing the cycle. There are two or three generations each year in the North and several in the more southern latitudes.

Known predators are stink bugs and *Polistes* wasps. Probably the most common and effective parasite is the braconid, *Apanteles glomeratus* (L.), (Fig. 300), but the chalcid, *Pteromalus puparum* (L.), and the tachinid, *Phryxe vulgaris* (Fallen), are of importance in some seasons.

Dusting or spraying with insecticides is necessary to control cabbage worms. Begin the applications when the caterpillars appear, and repeat at seven- to ten-day intervals until the infestation is checked.

Insecticides that have given satisfactory control are DDT, methoxychlor, carbaryl, rotenone, malathion, endosulfan, mevinphos, naled, parathion, metasystox-R, dimethoate, toxaphene, guthion, mixtures of toxaphene plus DDT or parathion, and *Bacillus thuringiensis*. The home gardener is urged to use methoxychlor, DDT, rotenone, malathion, or carbaryl.

References: *U.S.D.A. Cir.* 615, 1942; *Farmers' Bul.* 2099, 1960; *Agr. Handbook* 290, 1965; *Can. Dept. Agr. Pub.* 97, 1953; *Proc. Ent. Soc. Ont.* 93:85–87, 1963; *Ohio Ext. Bul.* 459, 1966.

CABBAGE LOOPER

Trichoplusia ni (Hbn.), FAMILY NOCTUIDAE

Widely distributed in North America, this light green caterpillar, with a few white or pale yellow stripes and only three pairs of prolegs, is often found feeding on cabbage and related plants (Fig. 301). In addition, beans and lettuce are sometimes seriously damaged as well as some greenhouse crops. Its work is often mistaken for that of the butterfly larva, and the two may be found on the same plants. The adult of the looper has dark brown, mottled fore wings, each having a small silvery spot resembling a figure 8 near its center; the hind wings are almost uniformly light brown. The moths have a wingspread of slightly more than $1\frac{1}{2}$ inches.

The loopers winter in the pupal stage, the pupae being enclosed in flimsy silken cocoons attached to the food plants or to nearby objects. Moths emerge in the spring and deposit dome-shaped, pale green eggs on the host plants, chiefly at night. After hatching, the destructive larval stage reaches full development in two to four weeks; pupation then occurs and in almost ten days the new adults emerge. Three or more generations are produced each season, depending on the latitude.

There is a high degree of natural control of this insect. Several parasites are usually numerous, a common species being the encyrtid, *Copidosoma truncatellum* (Dalm.). Predators attack it freely and there is often a high mortality from a polyhedral virus disease. Plowing in the spring to bury the overwintering pupae on crop remnants before emergence of adults is advisable. Insecticidal control is secured by the chemicals recommended for the imported cabbage worm with the exception of DDT, methoxychlor, and *Bacillus thuringiensis*. Pyrethrum insecticides are generally more effective for the looper than for other species of cabbage worms. This pest has developed resistance to insecticides in some regions.

References: *U.S.D.A. Tech. Bul.* 846, 1944; *Farmers' Bul.* 2099, 1960; *Agr. Handbook* 290, 1965; *Proc. Ent. Soc. Ont.*, 93:61–75, 1963; *J. Econ. Ent.*, 54:47–50, 141–146, 1961.

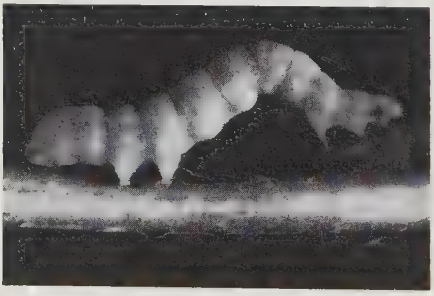


Fig. 301. The cabbage looper. (Pettit, Mich. Agr. Exp. Sta.)

DIAMONDBACK MOTH

Plutella maculipennis (Curtis), Family Plutellidae

An introduced species, this moth is widespread in North America but does commercial damage only in limited areas; during periods of several years it may attract no attention as a pest. Figure 302 shows the form of the moth and the nature of the work of its larva. When the moth is in its normal resting position, it is about $\frac{1}{3}$ inch long, and the light-colored areas which show as anal margins of the fore wings in the picture fit together to form diamond-shaped spots, the basis for the common name.

The diamondback winters as a moth, hibernating for a short period or remaining active through the winter, depending on the prevailing weather. Tiny eggs are laid on the leaves of cabbage and related hosts. On hatching the pale green larvae chew small cavities and holes in the leaves, feeding mainly on the undersides. In about two weeks they become fully developed, spin a loose mesh silken cocoon and change to pupae, the moths emerging a week or more later. As many as seven generations have been observed in regions where there is a hibernating period.

A small ichneumon wasp, *Horogenes insularis* (Cresson), has been recorded as parasitizing as many as 95% of these insects. Other species parasitic on the diamondback larva are *H. plutellae* (Viereck) and *Diadromus plutellae* (Ashmead).

The control practices recommended for suppression of the other worms on cabbage and related plants are effective for the diamondback larvae (p. 351).

Fig. 302. The diamondback moth, *Plutella maculipennis* (Curtis), and larval damage to a leaf. (U.S.D.A.)

Fig. 303. Larva of the horse-radish flea beetle, *Phyllotreta armoraciae* (Koch). (U.S.D.A.)

References: *J. Agr. Res.*, 10:1–10, 1917; *U.S.D.A. Farmers' Bul.* 2099, 1960; *Proc. Ent. Soc. Ont.*, 93:61–75, 1963.

FLEA BEETLES

ORDER COLEOPTERA, FAMILY CHRYSOMELIDAE

Flea beetles are general feeders and are frequently found on the foliage of vegetable and flower garden plants, where they chew small holes through the leaves from the underside, producing a shot-hole or sieve-like appearance. The larvae of many species feed on the underground parts of their host plants, and others feed on the stems and foliage. Some species may also be vectors of organisms causing plant diseases. These insects derive their common name from the fact that they are provided with well-developed hind legs and, when disturbed, jump in a manner resembling fleas.

The horseradish flea beetle, *Phyllotreta armoraciae* (Koch), is most commonly found on horseradish and wild mustard. Larvae mine in stems and leaf veins (Fig. 303). Adults are almost $\frac{1}{8}$ inch long, black, with a yellow stripe on each wing cover.

Fig. 304. The striped flea beetle, *Phyllotreta striolata* (F.): *a*, larva; *b*, adult; *c*, adult of the western black flea beetle, *P. pusilla* Horn. (U.S.D.A.)

The striped flea beetle, *P. striolata* (F.), is very common and widely distributed, and attacks cabbage, turnips, radishes, and related plants (Fig. 304).

The western striped flea beetle, *P. ramosa* (Crotch) is mainly southwestern in distribution and feeds on crucifers, weeds, and other plants.

The western black flea beetle, *P. pusilla* Horn, is found mostly from Canada to Texas westward to the coast. It is shiny, bronze-black, and attacks flowers and weeds, as well as crucifers (Fig. 304).

All species have very similar life cycles. Usually two or more generations are produced annually, depending on the latitude, and the adults pass the winter hidden under plant remnants. Other species of flea beetles are discussed in detail in Chapters 9, 12, and 13. Recommended control measures for them are also applicable for this group of flea beetles (pp. 289, 330).

RED TURNIP BEETLE

Entomoscelis americana Brown, Family Chrysomelidae

The approximate range of this pest is north and west from Colorado into Canada. Feeding on the leaves of cabbage, turnips, radishes, and garden beans may be so great as to require control measures. The adult is a reddish beetle $\frac{1}{4}$ inch long, marked with three black lines on the elytra and a broad median stripe on the thorax. Suggested control measures for the adults are the same as for flea beetles. Fall cultivation to bury the wintering eggs is advised by Dustan in Canada.

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Insects Injurious to Asparagus, Beets, Onions, and Other Vegetable Crops

ASPARAGUS BEETLE

Criocerus asparagi **(L.), FAMILY CHRYSOMELIDAE**

Introduced from Europe in 1860 this beetle has spread west over most of the areas of the United States where asparagus is grown.

The adult is $\frac{1}{4}$ inch in length, blue-black, with a reddish prothorax; the wings are marked with a characteristic pattern of creamy yellow spots with red borders. Dark gray, fleshy, soft-bodied larvae with black

Fig. 305. The asparagus beetle, *Crioceris asparagi* (L.); eggs, larva, and beetle. (Photographs by W. E. Britton.)

heads are about $\frac{3}{8}$ inch in length when fully grown. Eggs are slate black in color, elongate oval, and attached by one end to the stems of the host. The appearance of these stages is shown in Fig. 305.

Adult beetles hibernate and emerge about the time asparagus is cut for market. They chew portions of the green shoots, causing blemishes. In addition, the eggs are placed in abundance on the growing tips, making them unfit for market. Hatching may occur in a week, the larvae causing additional damage by devouring leaves and stems. In two or more weeks they become fully grown, drop to the ground, and enter the soil where pupation takes place. About ten days later the new adults emerge. There may be two or more generations each season.

To avoid poisonous residues during the cutting season, only rotenone, carbaryl, or malathion are recommended. For post-harvest treatments these same insecticides or DDT may be used to eliminate infestations. These late summer treatments greatly reduce the populations of beetles that eventually go into hibernation.

SPOTTED ASPARAGUS BEETLE

Criocerus duodecimpunctata (L.), Family Chrysomelidae

Although this insect was introduced from Europe only a few years after the advent of *C. asparagi*, it has not become so widely distributed, and is found primarily east of the Mississippi River. Except for the fact that the larvae of this species feed on or in the berries, there is little difference in the habits and life cycles of the two species. The adult

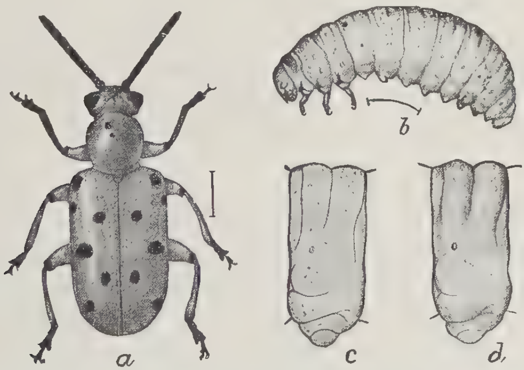


Fig. 306. The spotted asparagus beetle, *Crioceris duodecimpunctata* (L.): *a,* beetle; *b,* larva; *c,* second abdominal segment of larva; *d,* same of *C. asparagi*; *a, b,* enlarged; *c, d,* more enlarged. (Chittenden, U.S.D.A.)

beetle is orange-red with twelve black spots, and of a slightly heavier form than its congener (Fig. 306). The larvae are orange-colored. Control is achieved with the same insecticides recommended for *C. asparagi.*

References: *U.S.D.A. Farmers' Bul.* 837, 1917; *Home and Garden Bul.* 46, 1963; *N.Y. Agr. Exp. Sta. Cir.* 171, 1937.

ASPARAGUS MINER

Melanagromyza simplex (Loew), FAMILY AGROMYZIDAE

Occasionally injury by the small white larvae of this fly has been noted. These mine just beneath the surface of asparagus stems which weakens or sometimes kills that portion of the plant by girdling. Injury is most likely to occur in beds of seedlings or newly set plants but may also occur in older plants. The appearance and size of the fly and larva are illus-

Fig. 307. The asparagus miner, *Melanagromyza simplex* (Loew): (left) side view of fly; *a,* larva; *b,* thoracic spiracles; *c,* anal spiracles; *d,* puparium from side; *e,* same from above; *f,* section of asparagus stalk showing injury and location of puparia on detached section; *a, e,* much enlarged; *f,* slightly reduced. (Chittenden, U.S.D.A.)

trated (Fig. 307). Puparia of this fly pass the winter in stalks of asparagus. Adults appear in May and again in late summer. Eggs are laid near the base of the stalks, and the larvae tend to work upward. Unless the insect becomes more abundant and destructive than it hitherto has been, the only control needed is the destruction of stalks which show evidence of the presence of maggots. Diazinon, parathion, or DDT spray or dust applications timed to kill adults before eggs are laid should be effective in controlling this pest.

Reference: *Cornell Agr. Exp. Sta. Bul.* 331, 1913.

BEET LEAFHOPPER

Circulifer tenellus (Baker), Family Cicadellidae

Occurring in the arid and semiarid regions of western United States, northern Mexico, and southwestern Canada, this insect attacks red beets, sugar beets, beans, tomatoes, melons, spinach, ornamental plants, and many weeds. Some damage is caused by the piercing-sucking nymphs and adults feeding on plant sap, causing curling, stunting, and distortion. The most serious damage results from a plant disease known as "curly top," the virus organisms causing it being carried only by the beet leafhopper. The organisms survive the winter in the bodies of the leafhoppers, which then become the source of infection the following year. Leafhoppers transmit the virus during feeding.

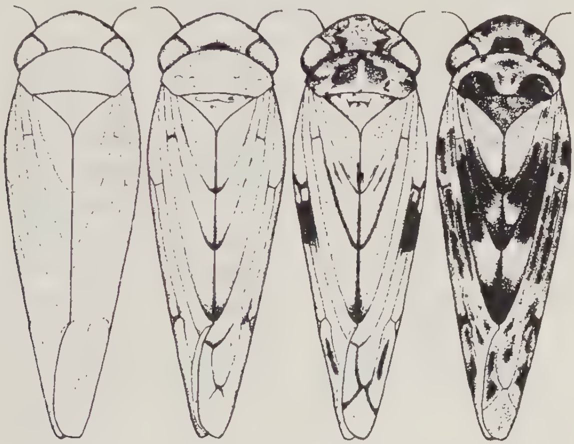


Fig. 308. The beet leafhopper, *Circulifer tenellus* (Baker), showing variation in color patterns. (Knowlton, Utah Agr. Exp. Sta.)

The beet leafhopper is $\frac{1}{8}$ inch in length, pale green to tan, sometimes with darker markings (Fig. 308). This stage overwinters chiefly in uncultivated and overgrazed areas where mustards, desert plantains, flixweed, pepperweed, and other weeds grow. Activity and feeding continue during the winter whenever temperature permits. Oviposition takes place when the plants begin spring growth, the eggs being inserted inside the tissues of leaves and stems. Each female deposits three hundred to four hundred eggs. Hatching occurs in five to forty days depending on the temperature, and the tiny nymphs feed and molt five times before reaching the adult stage. Development from egg to adult requires one to two

months. Generations overlap considerably, three being produced in northern areas and five or more in Arizona and California. The first generation is on spring weed hosts, chiefly mustards; later generations are on Russian thistle, many other weeds, and cultivated crop plants.

Natural control results from many parasites and predators. The chief parasites are the Strepsiptera, dryinid wasps, and the big-headed fly, *Tomosvaryella subvirescens* (Loew). Important predators are a lygaeid bug, *Geocorus pallens* Stål, a damsel bug, *Nabis americoferus Carayon,* spiders, lizards, and birds.

Early planting, controlling weed hosts in major breeding areas by proper land management, replacement of weed hosts with perennial grasses which are not leafhopper-breeding hosts, and guarding against overgrazing are cultural control measures of some practical value.

Reducing curly-top infection in susceptible crops by controlling the leafhopper with insecticides is a difficult problem because of the possibility of continuous reinfestation. Three or four weekly applications of 1 pound of actual DDT per acre during the spring migration period reduce leafhopper numbers and curly-top infection. However, this does not prevent the feeding of all leafhoppers that reinfest the fields. Applying oil solution or an emulsion containing DDT to weed host-breeding areas has proved practical. Use either aircraft or mist blowers with 1 pound of DDT in 2 gallons of spray per acre before migration of hoppers to cultivated areas. Some states recommend dosages two or even three times those given here. Parathion and phorate are other control chemicals.

References: *Utah Tech. Bul.* 234, 1932; *U.S.D.A. Tech. Bul.* 607, 1938; *Cir.* 518, 1939; *Tech. Bul.* 848, 1943; 855, 1943; 897, 1945; *Yearbook of Agriculture,* pp. 544–550, 1952; *Tech. Bul.* 1155, 1957; *Prod. Res. Rept.* 18, 1958; *Leaflet* 389, 1964; *J. Econ. Ent.,* 57:85–89, 1964.

BEET ARMYWORM

Spodoptera exigua (Hübner), Family Noctuidae

A somewhat smaller relative of the fall armyworm, this species has a general resemblance to the more important species. Its fore wings are dark with mottled lighter markings, and the hind wings are very thinly covered with whitish scales. The insect ranges throughout most of southern United States. Besides beets, it also feeds on asparagus, cotton, lettuce, peas, peppers, and many weeds.

The larvae are indistinctly striped green caterpillars, which reach a length of $1\frac{1}{4}$ inches (Fig. 309). The insect winters in the adult stage, and the early brood of larvae which usually do not attract attention feed on forage crops and weeds. This is followed by a second brood, and many larvae may invade beet fields and defoliate thousands of acres. In Florida

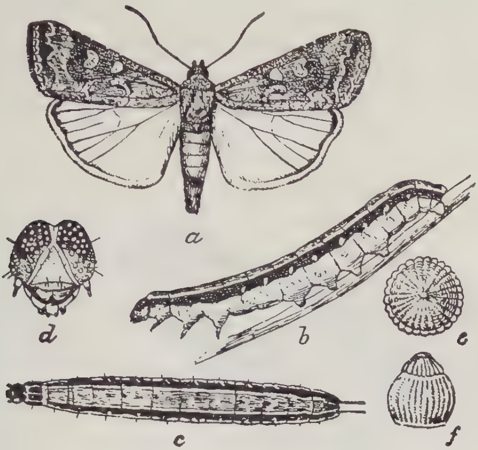


Fig. 309. The beet armyworm, *Spodoptera exigua* (Hübner): *a,* moth; *b,* larva, side view; *c,* larva, back view; *d,* head of larva; *e,* egg from above; *f,* egg from side; all enlarged. (Chittenden, U.S.D.A.)

there is no hibernation, and all stages of the insect may be found throughout the year.

The control measures are the same as those recommended for the armyworm (p. 145).

References: *Fla. Agr. Exp. Sta. Bul.* 271, 1934; *J. Econ. Ent.*, 54:192–193, 1961; *U.S.D.A. Agr. Handbook* 253, 1963.

BEET WEBWORM

***Loxostege sticticalis* (L.), Family Pyralidae**

Although this species is designated the beet webworm, sometimes the sugar-beet webworm, it has as much claim to the name garden webworm as the insect to which the latter name is applied. The beet webworm is an important pest of sugar beets, and attacks table beets, mangel-wurzels, other garden or field crops, as well as weeds. Damage is caused by the webbing larvae devouring the foliage. It is distributed from Canada to Texas westward as a pest of importance, but it is also present in some eastern states.

The brown moths have wings marked with darker and lighter spots, and a wing expanse of about 1 inch. Larvae are rather slender, green to yellow with a dorsal black stripe, and attain a length of 1 inch (Fig. 310). The larvae hibernate in the soil in long silken tubes where they pupate in the spring, emerging as moths about May. Eggs are laid in rows usu-

ally on the undersides of leaves. Newly hatched larvae feed largely on alfalfa and weeds. There is some tendency for these caterpillars to migrate from one field to another or from weed patches into cultivated crops. When fully developed, pupation takes place a few inches below the soil

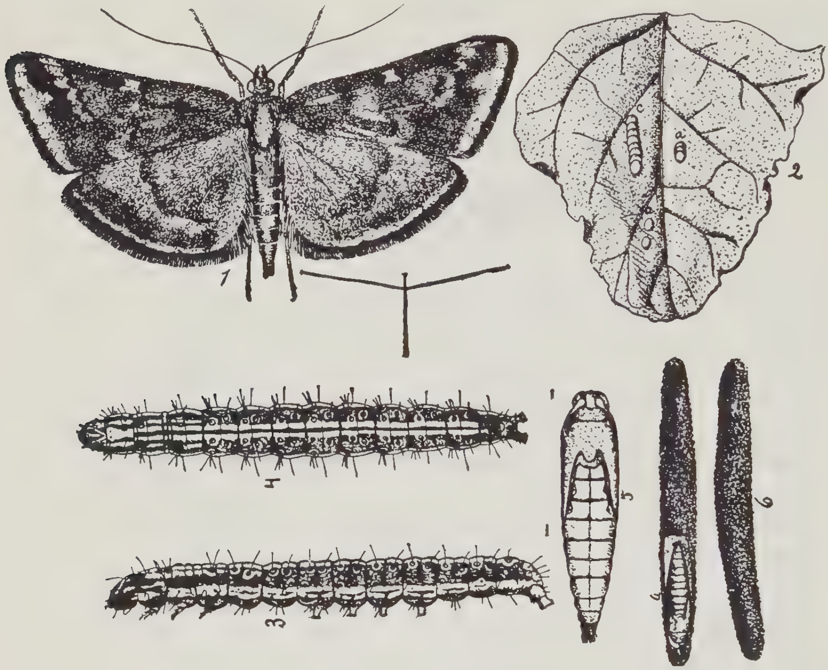


Fig. 310. The beet webworm, *Loxostege sticticalis* (L.): 1, moth; 2, eggs; 3, 4, larvae; 5, pupa; 6, winter tube of larva, opened at *a* to show pupa; 1, 3, 4, 5, enlarged. (Colo. Agr. Exp. Sta.)

surface, and new adults emerge in two or more weeks. These appear in July, and a third generation sometimes develops in August. There may be a fourth generation in more southern areas.

Clean culture, destruction of weed hosts which harbor the worms, and, when possible, deep plowing at the time of pupation help prevent injury.

Spraying or dusting with DDT, toxaphene, parathion, phosphamidon, Dylox, or pyrethrum controls the larvae, especially the early instars. If foliage is to be eaten apply only pyrethrum.

References: *Colo. Ent. Cir.* 58, 1933; *Mont. Agr. Exp. Sta. Bul.* 389, 1941; *U.S.D.A. Home and Garden Bul.* 46, 1963; *Agr. Handbook* 290, 1965; *J. Econ. Ent.*, 56:248–251, 1963.

OTHER BEET WEBWORMS

Order Lepidoptera, Family Pyralidae

The spotted beet webworm, *Hymenia perspectalis* (Hübner), is widely distributed in the world. In the United States it is sometimes injurious in late autumn as far north as New York City. The moth is described as coppery-brown, the wings marked with white (Fig. 311). Larvae are green with purple spots on the head and dark tubercles on the body segments. The host plants and the damage caused by the larvae are the same as described for the beet webworm.

The Hawaiian beet webworm, *Hymenia recurvalis* (F.), is similar to its congener in distribution, size, and habits, but it is darker in color with much more conspicuous white markings. Damage by the larvae is similar to that of the beet webworm. There are several generations per year in warmer climates.

Both these insects are controlled by the same insecticides recommended for the beet webworm (p. 361).

References: *U.S.D.A. Bul.* 109, 1911; *Bul.* 127, 1913.

Fig. 311. Adult ♂ above and ♀ below of the spotted beet webworm, *Hymenia perspectalis* (Hübner). (U.S.D.A.)

BEET LEAF BEETLE

Erynephala puncticollis (Say), Family Chrysomelidae

Injury from this insect is confined to the western sugar-beet-growing states, where it may do extensive damage, both adults and larvae devour-

Fig. 312. The beet leaf beetle, *Erynephala puncticollis* (Say). (U.S.D.A.)

ing the foliage. Table beets and spinach are also subject to attack. It occurs east to the Atlantic Coast but is rarely injurious there. The beetle is $\frac{1}{3}$ inch in length, dull yellow, with black along both the inner and outer margins of the elytra and with black spots on the prothorax (Fig. 312). The larvae resemble those of lady beetles. They are slaty to olive brown and marked with raised tubercles and yellow spots. Adult beetles hibernate, emerge in late spring, and produce two generations, with a partial third in some localities.

Sprays or dusts of DDT, rotenone, malathion, or methoxychlor would doubtless be effective, but there are no records of their application being necessary.

SUGAR-BEET ROOT APHID

***Pemphigus populivenae* Fitch, Family Aphididae**

This aphid is usually of little importance, but in certain years it has been the most serious enemy of commercial beets in some of the western states. The aphid passes the winter in the egg stage on cottonwood. Early generations cause galls to form on the petioles of these trees; migration to beets takes place early in the season, and feeding on the root sap of beets and related plants continues through the summer. In the fall, winged migrants fly back to cottonwood and produce sexual stages which mate and lay the overwintering eggs. Excess moisture is unfavorable to the root aphid, and, where irrigation is possible, injury can be prevented.

To control this insect apply 5% malathion dust at 30 pounds per acre, or a spray containing 1.5 pints of 50% malathion emulsifiable, or 1 pint of 40% TEPP to 100 gallons of water per acre.

Reference: *Utah Ext. Cir.* 214, 1954.

SUGAR-BEET ROOT MAGGOT

Tetanops myopaeformis (Röder), Family Otitidae

This maggot is an occasional pest of sugar beets in Utah and nearby states. It causes severe injury in some parts of individual fields, particularly in dry sandy soil. The maggots feed on the taproot of sugar beets, sometimes cutting it off, resulting in death of the plant. Adult flies are $\frac{1}{4}$ inch in length and black-bodied. The larvae are white, tapered maggots (Fig. 313). Winter is passed in the soil, and one or two generations are produced each season.

Where possible irrigation, to keep the soil-moisture content up, will result in the maggots feeding high enough to prevent injury to the taproot.

Seed treatment by mixing 8 ounces of 0.75% WP dieldrin or aldrin with 100 pounds of sugar-beet seed has been effective in controlling this pest. Check with the extension entomologist in your area for the latest control recommendation.

References: *Utah Leaflet* 22, 1934; *U.S.D.A. Farmers' Bul.* 1903, 1942; *Agr. Handbook* 290, 1965.

SPINACH FLEA BEETLE

Disonycha xanthomelas (Dalm.), Family Chrysomelidae

Most of the garden flea beetles discussed previously (pp. 289, 354) attack red beets, sugar beets, and spinach, but this species is somewhat

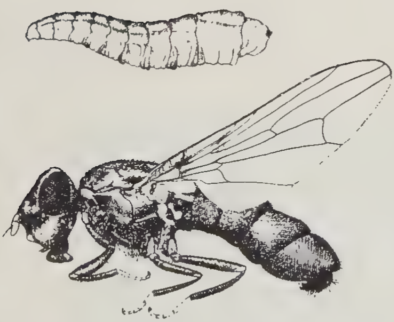


Fig. 313. Larva and adult of the sugar-beet root maggot. (Knowlton, Utah Agr. Exp. Sta.)

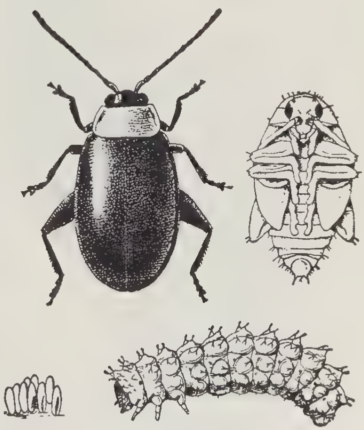


Fig. 314. Life stages of the spinach flea beetle, *Disonycha xanthomelas* (Dalm.).

more specific to these hosts. Both adults and larvae devour the foliage. The adult is nearly $\frac{1}{4}$ inch in length, the head is black, the wing covers of a blue-green luster, the prothorax and abdomen orange-yellow, and the appendages black (Fig. 314).

Hibernating beetles emerge and lay eggs on the host plants. On hatching, the dull gray larvae feed on the leaves and reach a length of $\frac{1}{3}$ inch before pupating. There are usually two generations, the earlier one developing on weed hosts for the most part, the latter one on beets and spinach.

To control this pest on spinach or other leafy food plants, apply 1% rotenone dust at 25 to 30 pounds per acre or a spray containing 4 pounds of derris or cubé powder (4% rotenone) in 100 gallons of water per acre. On other hosts, the leaves of which are not utilized for food, apply 5% DDT dust or 2 pounds of 50% wettable powder in 100 gallons of water per acre.

SPINACH LEAF MINER

Pegomya hyoscyami **(Panzer), Family Anthomyiidae**

Beets, spinach, chard, and related plants are damaged by larvae of a small fly, mining between the upper and lower leaf surfaces. Leaf crops

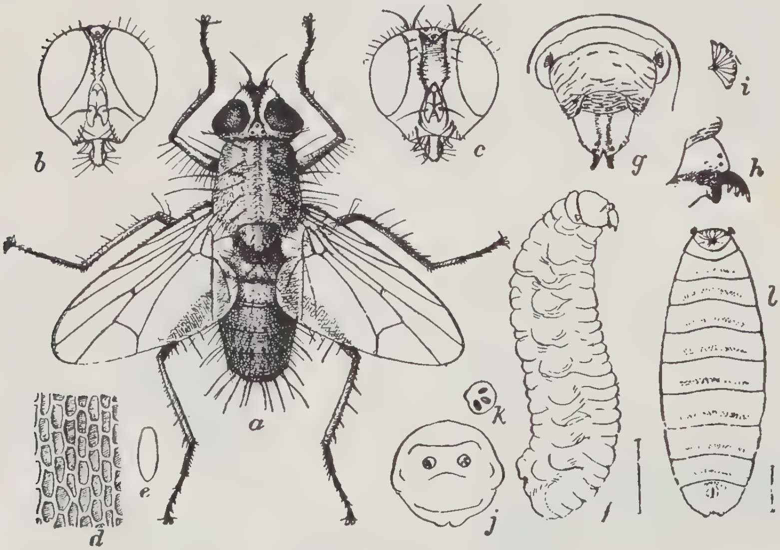


Fig. 315. The spinach leaf miner, *Pegomya hyoscyami* (Panzer): *a*, fly; *b*, head of male; *c*, head of female; *d*, surface of egg, highly magnified; *e*, egg; *f*, maggot; *g*, head of same; *h*, cephalic hooks of larva; *i*, thoracic spiracle; *j*, anal segment; *k*, anal spiracles; *l*, puparium; all enlarged. (Howard, U.S.D.A.)

are made unfit for food, and the photosynthetic surface is reduced for proper development of root crops. Most of the damage is noticed late in the growing season. The winter is passed as puparia in the soil. Adult flies (Fig. 315) emerge in the spring and lay eggs on the leaves of the host plants. After hatching the tiny maggots mine into the leaves and, when fully grown, drop to the ground and change into puparia. In a few weeks new adults emerge and soon lay eggs of the next generation. There are three or more generations annually.

Deep plowing in early spring and destruction of wild hosts, as well as of cultivated infested plants or leaves, are suggested cultural control measures. The chemicals suggested for the serpentine leaf miner (p. 327) should be of value in control. For edible crops, select the proper chemical, and time its application so as to avoid poisonous residues at harvest.

CARROT RUST FLY

***Psila rosae* (Fabr.), FAMILY PSILIDAE**

The rust fly is a native of Europe and was found in Canada in 1885. It has since spread to most of southern Canada and northern United States. Besides carrots, this insect also attacks parsnips, celery, parsley, and related plants. Damage is caused by the maggots burrowing into the roots, killing young seedlings, or impairing the market value of older roots by their rust-colored tunnels (Fig. 316). Heavy maggot feeding is indicated by drooping, discolored foliage.

The fly is shiny black, less than $\frac{1}{5}$ inch in length, with a pale yellow head, legs, and wings. They begin emerging from the overwintering puparia in the

Fig. 316. The carrot rust fly, *Psila rosae* (Fabr.), and work of the maggots. (Pettit, Mich. Agr. Exp. Sta.)

soil in early May and soon deposit tiny white eggs at the base of the host plants. On hatching, the slender white maggots feed, becoming fully developed in three or four weeks, then leave the roots and change to puparia in the soil. Second-generation adults appear from early July until late August. In some areas a third generation develops; these adults appear in September.

Delaying seeding until mid-May and harvesting early in July before the second-generation flies appear are means of avoiding injury. Rotation of crops, destroying wild hosts, and deep plowing in fall or spring are other control measures.

When the flies appear effective control is gained by scattering crude naphthalene over the foliage and soil of the carrot planting at the rate of 1 pound to 100 square feet. Dusting the crowns of the plants with calomel-talc mixture (4% calomel) at the rate of 1 pound to 200 feet of row at seven- to ten-day intervals is also of value. Heavy applications of 0.75% rotenone dust during the periods of adult flight have given good results. Treating the soil with chlordane and/or the seeds with diazinon is also recommended. Resistance to the chlorinated hydrocarbon insecticides has developed in some regions.

References: *Mass. Agr. Exp. Sta. Bul.* 352, 1938; *Can. Dept. Agr. Pub.* 91, 1951; 939, 1955. *J. Econ. Ent.*, 52:963–966, 1959; 55:560, 777–780, 1962.

CARROT WEEVIL

Listronotus oregonensis (LeC.), FAMILY CURCULIONIDAE

This weevil is known to exist in the states from Virginia to New York and Connecticut; it has also been found in Illinois and Iowa. Carrots are the plants most often attacked, but it may feed on celery, parsley, parsnips, dill, wild carrot, plantain, and dock.

The adult beetle is nearly $\frac{1}{4}$ inch in length, dark brown, with typical chewing mouthparts of weevils. The larvae are white, legless, curved grubs which cause most damage by boring into roots and stems. Eggs are usually laid in stems, the larvae boring downward and doing their most destructive work to the roots of carrots; in celery the damage may be largely to the stalks. Hibernating adults become active in May, or earlier, and by July beetles of the first generation are mature. It is reported that there may be a partial second generation.

The beetles fly, but apparently they do not travel far. Consequently, the removal of plantings of susceptible crops to uninfested ground is an effective control measure.

Pre-emergence treatments with some of the chemicals recommended for controlling wireworms are suggested for reducing populations of this pest but poisonous residues on edible crops may be a problem. Obtain the latest chemical control recommendations for your area.

References: *Cornell Ext. Bul.* 206, 1931; *N. J. Agr. Exp. Sta. Bul.* 693, 1942; *J. Econ. Ent.*, 50:183–184, 797–799, 1957.

CARROT BEETLE

Bothynus gibbosus **(DeGeer), Family Scarabaeidae**

Widely distributed over most of the United States except the most northern states, the adult carrot beetle attacks the roots and foliage of carrots, celery, corn, potatoes, parsnips, sugar beets, and sweet potatoes. The larvae are root feeders as well as scavengers, and soils high in organic matter seem to favor the development of populations.

Fig. 317. The carrot beetle.

Carrot beetles are broad, stout, red-brown, and about $\frac{1}{2}$ inch long (Fig. 317). They hibernate deeply in the soil and appear in the spring. Eggs are laid in the soil, and the hatching larvae resemble white grubs, being curved and white, often with a blue tinge. When fully grown they are over an inch long. There is but one generation a year.

Plowing in the fall reduces populations of the carrot beetle. Chemical control measures consist of treating the soil with insecticides as recommended for white grubs (p. 139).

References: *U.S.D.A. Farmer's Bul.* 2168, 1963; *Agr. Handbook* 264, 1964.

CELERY LOOPER

Anagrapha falcifera **(Kirby), Family Noctuidae**

This looping caterpillar devours the leaves of beets, beans, celery, lettuce, and other plants. The adult is a moth resembling the adults of the cabbage looper and several of the cutworms. Its markings are shown in Fig. 318. Larvae are pale green with rather faint stripes, the body tapering toward the head, with three pairs of abdominal prolegs. Along the sides of the abdomen is a row of small black spots, each spot having a white dot in the center. These mark the spiracles. Winter is passed in the partly grown larval stage, and development is completed in the spring; there are three

Fig. 318. The celery looper, *Anagrapha falcifera* (Kirby): male moth and larva. (Chittenden, U.S.D.A.)

generations through the central part of the range of this pest. Control is attained with dusts containing either 5% DDT, 1% rotenone, or 0.2% pyrethrins. Only rotenone or pyrethrum should be applied on edible vegetable crops.

Reference: *U.S.D.A. Farmers' Bul.* 1269, 1944.

CELERY LEAF TIER

Udea rubigalis (Guenée), Family Pyralidae

This insect is also known as the greenhouse leaf tier because it often becomes a serious pest of greenhouse crops. Besides celery it also attacks cabbage, beets, spinach, tobacco, many flower garden plants, and weeds. In the gardens of the North it usually is not a problem pest; in Florida it is one of the major insects attacking celery.

The larva is light green, with dorsal lighter and darker stripes. Fully grown, it is about $\frac{3}{4}$ inch long. It feeds on the inner surface of the folded leaves, which are webbed with silk, but may also eat into buds and flowers. Pupation takes place in a silken cocoon inside the rolled edge of a leaf.

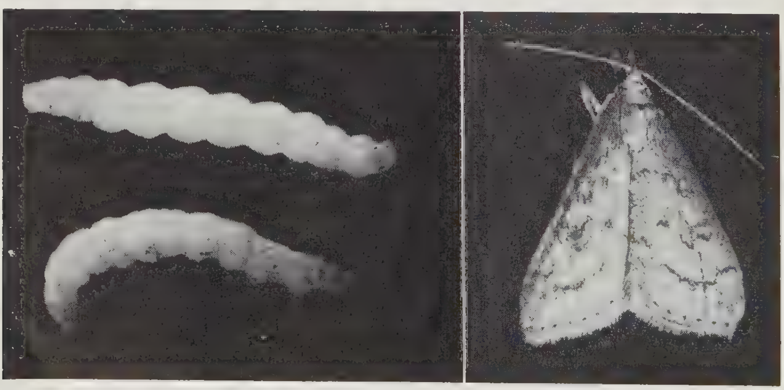


Fig. 319. The celery leaf tier, *Udea rubigalis* (Guenée). (Mich. Agr. Exp. Sta.)

New tan-colored moths with darker irregular markings and a wingspread of nearly $\frac{3}{4}$ inch (Fig. 319) emerge in about ten days. Tiny, pale green eggs are soon deposited on the leaves, and the life cycle is repeated. There are several generations each year. In the greenhouse a generation may be completed in thirty-five to forty days.

On young plants control can be attained with 5% DDT dust; near harvest, on edible plant parts apply a dust containing 0.2% pyrethrins, with two applications thirty minutes apart. Repeat applications should be made as needed. In the greenhouse, aerosols of either DDT or parathion control this insect.

References: *Mich. Quart. Bul.*, 14:91, 1931; *Fla. Bul.* 251, 1932; *J. Agr. Res.*, 29:137–158, 1924; *U.S.D.A. Tech. Bul.* 463, 1935.

SWEETPOTATO WEEVIL

Cylas formicarius elegantulus (Sum.), FAMILY CURCULIONIDAE

This weevil is the worst pest of sweet potatoes in the areas where it is now found. Of tropical origin it is distributed in much of Louisiana and Florida, many counties of southern and eastern Texas, the coastal counties of Mississippi, Alabama, Georgia, and South Carolina. It is also present in Hawaii. Other hosts are morning-glories and related species.

The beetle is $\frac{1}{4}$ inch long, dark blue on the head, snout, and back, and brick red on the prothorax and legs. It resembles a large ant (Fig. 320). Eggs are laid in the plants near the surface of the soil. In warm weather hatching occurs in about a week, and the white, legless larvae with pale brown heads feed and develop, attaining a length of $\frac{3}{8}$ inch. These larvae or

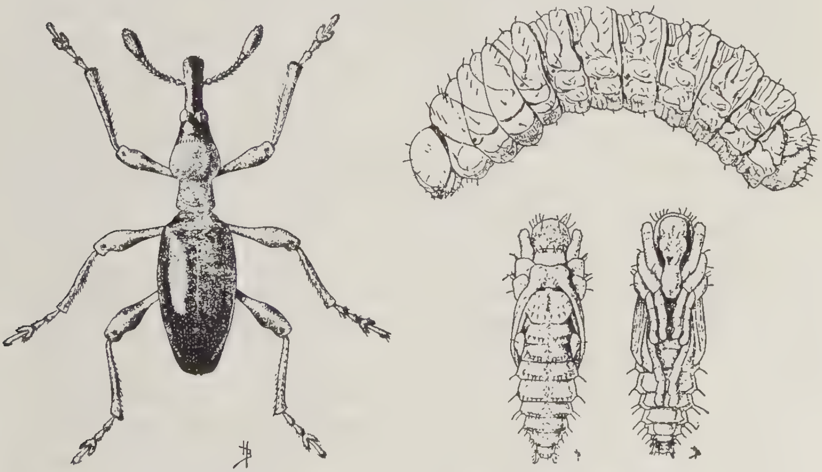


Fig. 320. The sweetpotato weevil; adult beetle, larva, and pupae. (U.S.D.A.)

grubs bore into the vines and through the roots and tubers, resulting in death of the plants and unmarketable tubers. After a week or more in the pupal stage inside the tubers, the adults emerge and feed on the leaves, vines, and roots, soon laying eggs which develop into the next generation. In the Gulf states there are as many as eight generations each year. Weevils continue to feed and breed in sweet potatoes in storage, although development is retarded.

The control program for the weevil includes several operations. At least one month before the new crop is planted, there should be a thorough cleaning of all sweetpotato storage places and complete destruction of all infested potatoes. Then dust or spray the storage place with DDT. Apply 1 pound of 10% DDT dust to each 1600 square feet of surface. For spraying add 8 pounds of 50% DDT wettable powder to 100 gallons of water, and apply at the rate of 1.5 gallons to each 1000 square feet. Use only state-certified seed sweet potatoes. If seed is selected at harvest, treat it with 1 pound of 10% DDT dust to each 6 to 8 bushels. Destroy all the vines and sweet potatoes in the seed beds as soon as sufficient plants have been obtained for the new crop. Place, where possible, in fields which were not planted with sweet potatoes the season before, and as far from such fields as feasible. Set the plants deeply, and mound up the soil to protect the stems and make it difficult for the grubs to reach the roots. Keep volunteer plants destroyed, and harvest promptly and cleanly, leaving no culls in the field. Turning hogs into the field after the crop is harvested assists in cleaning up vines and small potatoes. Fumigating infested sweet potatoes with methyl bromide at the rate of 1 pound per 1000 cubic feet of storage space prevents development of the weevil in storage and insures insect-free seed. A preplanting dip for the sweetpotato cuttings, consisting of 2 pounds of actual DDT in 100 gallons of water, followed by 5 spray applications during the season, has given excellent control. Treating the top layers of the soil with 10 pounds of DDT per acre has also controlled the weevil. Quarantines are maintained in the principal sweetpotato-growing states to prevent introduction and spread of the weevil and to assist in eradication campaigns.

References: *J. Econ. Ent.*, 44:652–656, 1951; 46:389–393, 1953; *U.S.D.A. Leaflets* 121, 1954; 431, 1960.

SWEETPOTATO LEAF BEETLE

Typophorus nigritus viridicyaneus (Crotch), Family Chrysomelidae

This is a minor pest of the sweet potato, widely distributed throughout the United States from the Ohio River southward. The adults feed on foliage and the larvae bore into the roots and vines, damaging both (Fig. 321).

These beetles are shiny blue-green, $\frac{1}{4}$ inch in length. They begin to

Fig. 321. The sweetpotato leaf beetle, and work of its larvae. (U.S.D.A.)

emerge the latter part of May and are present until July. After a preoviposition period of two weeks, each female deposits small groups of lemon-yellow eggs in the soil near the base of the plants. Hatching occurs in nine days and the pale yellow larvae feed until fully developed, which is usually before harvest of the crop. They leave the roots, migrate downward in the soil, and pass the winter. Pupation begins in early May of the following year, the entire life cycle requiring almost a year.

Since most adults emerge from the soil within a period of about a week late in May or early in June, and there is a preoviposition period of about fourteen days, insecticides should be applied during this period to kill adults before eggs are deposited. Apply dusts containing 5% DDT or methoxychlor, or 70% cryolite, at 20 to 30 pounds per acre.

Reference: *U.S.D.A. Cir.* 495, 1938.

SWEETPOTATO FLEA BEETLE

Chaetocnema confinis Crotch, Family Chrysomelidae

The sweet potato flea beetle is a widely distributed species east of the Rocky Mountains. Feeding by this beetle is somewhat unlike that of other flea beetles. It cuts shallow irregular channels in both surfaces of the leaf, but it does not puncture the leaves. When these beetles (Fig. 322) attack very young plants, serious damage results, often requiring replanting. Larvae feed on the roots of bindweed but not on sweet potatoes. Other hosts are morning-glory, corn, wheat, oats, clover, and sugar beets.

Hibernating adults become active in late spring and attack newly set sweetpotato plants. Eggs are laid on bindweed, the white larvae developing

on the roots, with new adults appearing by late summer. These become the hibernating individuals; there is only one generation each year.

Delayed planting is a means of avoiding serious damage. Insecticide dusts of either 5% DDT, methoxychlor, malathion, or 1% rotenone at 20 pounds per acre will control the flea beetle. Apply when the beetles appear and repeat if necessary.

Reference: *N. J. Agr. Exp. Sta. Bul.* 229, 1910.

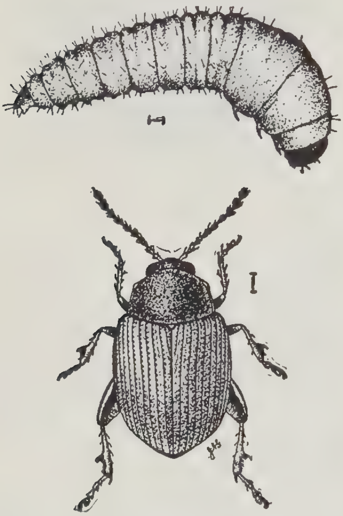


Fig. 322. The sweetpotato flea beetle, *Chaetocnema confinis* Crotch. (J. B. Smith.)

Fig. 323. Larvae of a tortoise beetle. (U.S.D.A.)

TORTOISE BEETLES

Order Coleoptera, Family Chrysomelidae

A group of leaf beetles, sometimes called tortoise beetles because the heads are concealed under the margin of the thorax, attack moonflower, Chinese lantern, sweetpotato, morning-glory, and bindweed, often with serious injury caused by the larvae (Fig. 323) and adults devouring the foliage.

Some common species are the argus tortoise beetle, *Chelymorpha cassidea* (Fabr.) (Fig. 324); the black-legged tortoise beetle *Jonthonota nigripes* (Oliv.); the mottled tortoise beetle, *Deloyala guttata* (Oliv.); the golden tortoise beetle, *Metriona bicolor* (Fabr.); and the striped tortoise beetle, *Agrioconota bivittata* (Say).

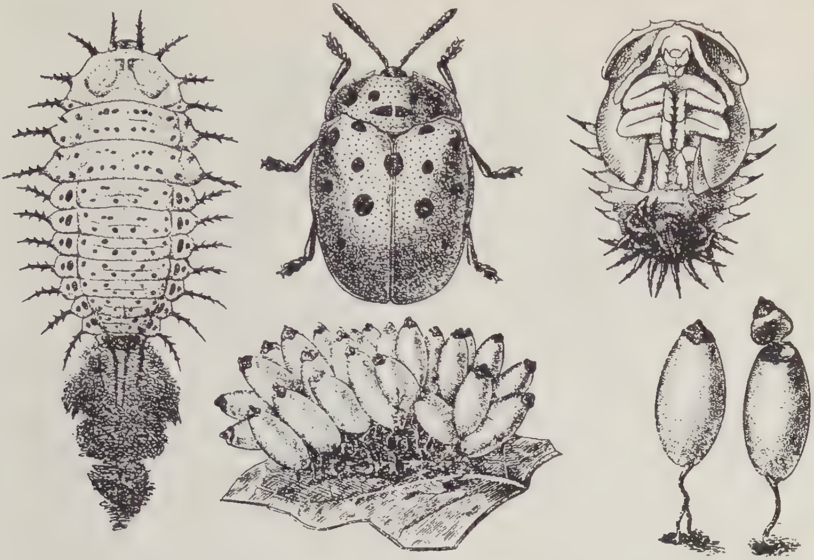


Fig. 324. Eggs, larva, pupa, and adult of the argus tortoise beetle, *Chelymorpha cassidea* (Fabr.). (U.S.D.A.)

The adults are oval, flattened beetles, nearly $\frac{1}{4}$ inch in length, with a color pattern indicated by the common name, except for the argus tortoise, which is orange-red with black spots, and about $\frac{3}{8}$ inch in length.

Larvae are short, flattened, spiny-margined, with a forked posterior appendage bent forward over the body to which is attached a mass of cast skins and excreta.

All species have similar life cycles. Adult beetles hibernate in the winter, become active in the spring, and feed on morning-glory or bindweed plants until sweet potatoes are planted. Eggs are laid about June, and the larvae feed on the foliage, later pupating on the leaves. New adults appear by midsummer and feed until fall. In more southern areas some species may produce several generations during the summer.

When the need for control measures is indicated, spray or dust with DDT, rotenone, methoxychlor, malathion, or carbaryl.

Reference: *J. Agr. Research*, 27:43–53, 1924.

ONION MAGGOT

Hylemya antiqua **(Meigen), Family Anthomyiidae**

This insect, generally considered the most serious pest of onions, is a native of Europe. It is found in this country in the northern states, and it is also established in Canada. The flies are slender-bodied, long-legged, and

Fig. 325. The onion maggot, *Hylemya antiqua* (Meigen); adult, puparium, and larva. (U.S.D.A.)

resemble the house fly (Fig. 325) except that they are only half as large. The larvae are typical white maggots, which burrow into the developing bulbs of the onion, causing the plants to turn yellow and die. Cool wet weather favors the development of serious infestations.

Hibernation takes place as puparia concealed in the soil or in the shelter of weeds or crop remnants. Emerging adults appear in the spring and lay their white eggs in the axils of the leaves and in the soil near the plant. When the onions are small and growing close together, a maggot may move from one to another and destroy several plants in the course of its development. When fully grown, they enter the soil, change to puparia, and in a few weeks emerge as adults, producing a second generation. In some areas a third generation often develops in onions before harvest.

Treatment of the furrow has become a widely adopted practice. At planting time introduce one of the following chemicals into the seed furrow either as a drench or as granules, at the dosage indicated per acre: 1 pound diazinon, 2 pounds trithion, $1\frac{1}{2}$ pounds ethion, 1 pound V-C 13. Do not apply V-C 13 to onions grown for the green or bunching market. Additional control measures consist of surface treatments of the growing onion plants with diazinon, malathion, naled, or parathion. These are directed at killing all the newly emerging adults before they lay eggs, therefore repeated applications will be required.

References: *Can. Dept. Agr. Bul.* 161, 1932; *Pub.* 135, 1961; *Ohio Ext. Bul.* 459, 1966; *J. Econ. Ent.*, 47:852–859, 1954; 56:580–584, 1963.

ONION THRIPS

***Thrips tabaci* Lindeman, Family Thripidae**

Thrips are serious pests in practically all onion-growing areas of the United States and Canada. Besides onions, many other vegetable and flower garden plants, as well as weeds, are hosts. Damage is caused by the nymphs and adults sucking the plant sap with their rasping-sucking mouthparts. This injury has the appearance of tiny white spots on the leaves, and when severe the entire plant may wilt and die.

In the North both adults and nymphs pass the winter concealed in grass stems or other plant remnants, whereas activity may continue the year around in warmer climates. Adult thrips are under $\frac{1}{16}$ inch in length, dark-bodied, with four wings fringed with hairs (Fig. 326). The females deposit eggs in tender plant tissues. The eggs hatch in a few days into tiny, wingless, almost white nymphs, which feed and molt four times before reaching the adult stage. Development from egg to adult may not require more than two weeks, resulting in several overlapping generations per season. These insects may feed between the leaves, well down toward the base of the plants, where it is difficult to reach them with insecticides.

Several species of lady beetles and the bug, *Orius insidiosus* (Say), are predators of thrips. Some varieties of sweet Spanish onions show resistance to thrips' attack.

Insecticide applications are the common and effective control measures. Sprays give better control than dusts, especially when a wetting agent is added. The following materials are recommended for controlling this insect: DDT, diazinon, malathion, parathion, mevinphos, toxaphene, and rotenone. Two or three applications about a week apart are usually sufficient to check an infestation; in some seasons, several more may be necessary. Because of

Fig. 326. The onion thrips, *Thrips tabaci* Lindeman. (U.S.D.A.)

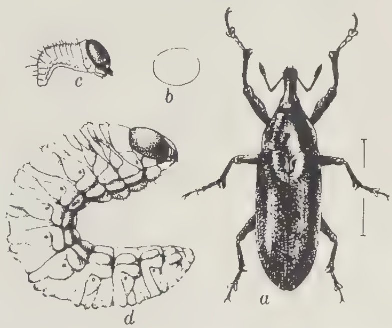


Fig. 327. The rhubarb curculio, *Lixus concavus* Say: *a*, beetle; *b*, egg; *c*, newly hatched larva; *d*, full-grown larva. (U.S.D.A.)

poisonous residues only malathion, rotenone, diazinon, or mevinphos should be applied to onions grown for the green or bunching market.

References: *U.S.D.A. Leaflet* 372, 1960; *Agr. Handbook* 313, 1966.

RHUBARB CURCULIO

Lixus concavus **Say, Family Curculionidae**

The adult rhubarb curculio is one of the largest snout beetles common to the eastern half of the country. It is $\frac{1}{2}$ inch in average length and nearly black in ground color (Fig. 327). Fresh specimens are so densely covered with rusty powder that they appear reddish. The beetle bores into the stalks of rhubarb with its chewing mouthparts and then lays eggs in the punctures, but the larvae practically never develop in that plant. The injury is merely the result of the punctures and the small amount of feeding by the adults on rhubarb foliage. Larvae develop in common curled dock, and on that plant most adult feeding occurs. The curculio is not considered a serious pest, but elimination of dock from the vicinity of rhubarb should be of value as a control measure.

16

Insects Injurious to Fruit and Shade Trees, and Ornamental Plants

Fruit growing is a very important industry in the United States and Canada, and in many areas of these countries it is impossible to produce a quality product unless both insects and diseases are controlled. In order to do this as economically as possible, both insecticides and fungicides are combined into a spray program. Such a program must be developed for each region, must include compatible chemicals that are effective in control, and must be the least hazardous from the standpoint of application and residues on the marketed product. Since many of these programs are complex and are prepared primarily for the experienced commercial grower many persons who normally enjoy growing small quantities of different fruits as a hobby are often denied this pleasure. Some all-purpose spray formulas have been developed for the amateur fruit grower that are relatively safe and effective if thoroughly applied. The following is a recommended mixture:*

		Amount Used for	
Materials		100 gal.	10 gal.
Methoxychlor	50% wettable powder	$2\frac{1}{2}$ lb.	4 oz.
Malathion	25% wettable powder	3 lb.	5 oz.
Captan		2 lb.	3 oz.

These ingredients may be purchased separately and mixed before application. Commercially blended mixtures are also available.

This formula is recommended for peaches, plums, sweet and sour cherries, grapes, red raspberries, blackberries, pears, quinces, and apples. Proper timing of the applications depends on the insects and diseases present in a

* C. R. Cutright, *Ohio Farm & Home Research*, 39:26–27, 1954.

given region. To determine the insects present and to learn the timing of spray applications for their control, reference should be made to this and the following five chapters. Generally, the first spray should be applied on stone fruits and berries when 95 to 100% of the peach petals have fallen, and should be repeated in ten days. After this, two more applications should be made at two-week intervals. Apples, cherries, pears, and quinces may be in full bloom when the first spray is needed on other fruits; in that event they should not be sprayed until their petals have dropped. Do not spray when any of the fruits are in blossom.

SAN JOSE SCALE

Aspidiotus perniciosus Comstock, Family Diaspididae

The San Jose scale was discovered in this country in the vicinity of San Jose, California, before 1880. It was brought to this country from Japan, but its original habitat seems to have been northern China. From California it was transported to the Atlantic seaboard on nursery stock, and from centers of infestation thus established it spread rapidly and now may be found throughout most of the United States and in Canada. In recent years it has not been a serious problem, thanks to effective insecticides and natural enemies.

San Jose scale attacks most cultivated fruits and a large number of ornamental shrubs and trees. Osage orange is often heavily infested and serves as a reservoir for reinfestation. Several forest trees maintain the insect, but injury is usually not serious. Vigor is reduced, and fruits are blemished by the nymphs and adults removing sap from any part of the plant but especially the wood. Diagnosis can be easily made by the encrusted scales on the branches and the tiny red circles with white centers on apple and pear fruits. Unchecked heavy infestation may kill trees.

The fully grown female scale is circular, about the size of a pinhead, dark brown to black, with a raised, dull yellow center (Fig. 328). Young scales are very light colored but soon become sooty black, often ashy in appearance. The male scales are smaller than the females and of oval form. Near the center of the scale is a depressed ring surrounding a raised center. Where this shows clearly it serves as a convenient means of identification.

Winter is passed in the partly grown nymphal stage under the scale coverings on the host plants. Development continues in the spring, and maturity is reached usually in May or June when minute, two-winged adult males (Fig. 329) appear which mate with the females under the edge of their scale coverings and die soon afterwards. The female produces young which crawl from under the edge of her covering. Newly born, lemon-yellow nymphs resemble mites, but they can be distinguished from them by the presence of three pairs of legs and a pair of antennae. They are

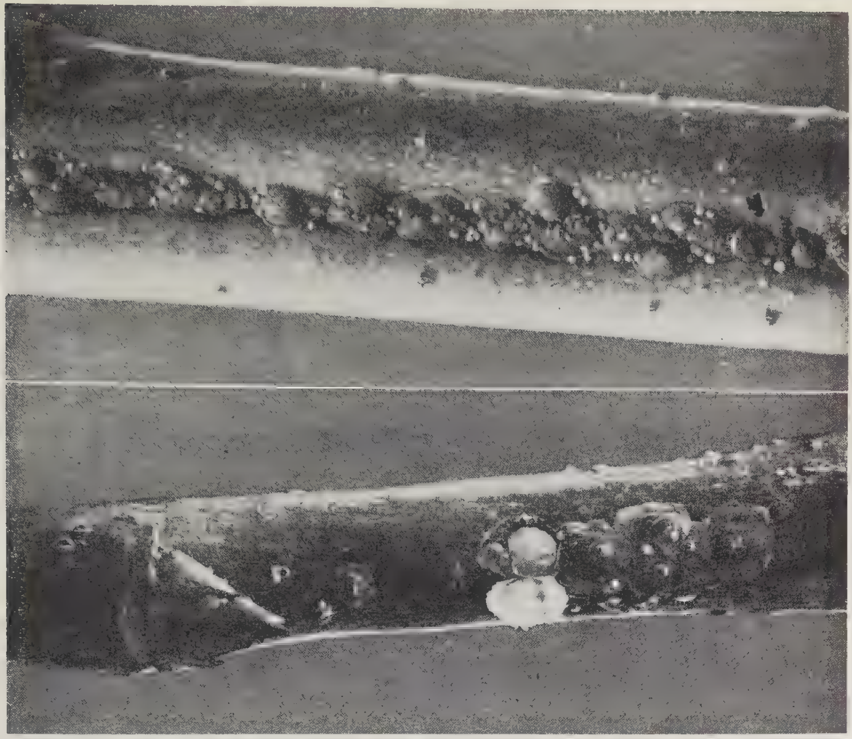


Fig. 328. Peach twigs infested with the San Jose scale. On the twig below a scale has been turned back to show the female insect; enlarged. (W. E. Britton.)

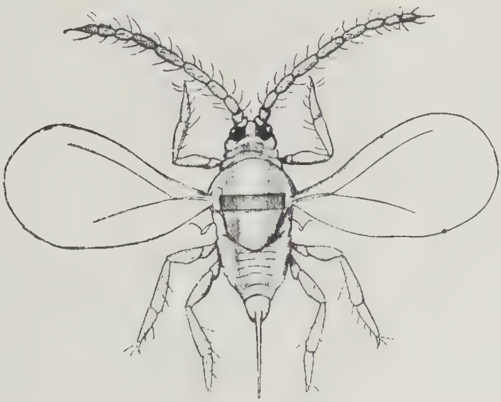


Fig. 329. Adult male San Jose scale, greatly enlarged. (Howard & Marlatt.)

called "crawlers" and migrate over the host for a few hours before inserting their mouthparts into the bark, leaves, or fruit to feed. After the first molt the legs and antennae are shed; these are incorporated in the scalelike covering, which increases in size as the nymphs continue to grow. Underneath these scalelike coverings may be found the yellow, nearly circular saclike bodies of the insects (Fig. 330). Growth is completed in about six weeks, and two or more overlapping generations are produced each season.

Local spread is accomplished by the crawlers. Many of these are doubtless carried from place to place on the feet of birds and on other insects. Some may be carried by the wind. Long-distance dispersal is largely through transportation of infested plants by man.

Natural control of this scale is exercised partly through climatic factors, extreme cold being fatal. Several parasitic wasps, principally *Aphytis* sp. and *Prospaltella* sp., as well as predatory lady beetles and mites, are very important in keeping populations checked.

An early effective insecticide was dormant-strength, liquid lime-sulfur (33° Baumé), diluted 1 part to 8 parts of water, applied in the spring before the buds burst. Dormant sprays containing 3% regular-type or 2% superior-type emulsifiable oils have largely replaced lime-sulfur for scale control because they are more effective and kill other insect life stages as well. With the addition of parathion, malathion, guthion, other phosphate type insecticides, and carbaryl to orchard-spray schedules, dormant sprays, especially in commercial orchards, are not as widely used. However, continuous application of most pesticides is favorable to the development of resistant strains of insects and mites, and dormant oil sprays still have a place in most spray schedules. Superior oil plus ethion is recommended in

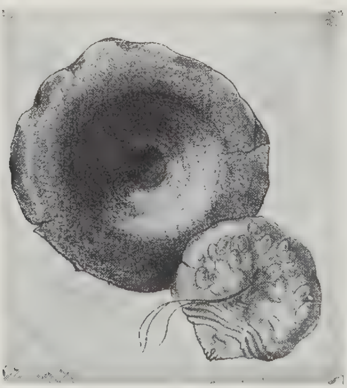


Fig. 330. Adult female San Jose scale, with scale removed to expose the insect. (Alwood.)

the delayed dormant period in some regions. All of these pesticides are effective in the control of this scale insect on shade trees and ornamental shrubs. Two or more sprays applied when the crawlers are present will usually suffice. Parathion is phytotoxic to McIntosh and Cortland varieties.

References: *U.S.D.A. Agr. Inf. Bul.* 272, 1963; *Calif. Agr. Exp. Sta. Leaflet* 76, 1966.

OYSTERSHELL SCALE

Lepidosaphes ulmi **(L.), Family Diaspididae**

World-wide in distribution oystershell scale is a pest of apple, pear, occasionally other fruit trees, and many shade and ornamental plants. Lilac and ash trees are often seriously attacked. Heavy infestations of these piercing-sucking insects greatly reduce plant vigor and often kill the host if no control measures are initiated.

The scale covering is brown, sometimes appearing gray, and shaped somewhat like oystershells (Fig. 331). The covering of the female is nearly $\frac{1}{8}$ inch long when completed, narrow at the anterior end and widened at the rounded posterior end. The covering of the males is smaller and more oval-shaped.

Winter is passed as minute white eggs beneath the scale of the female insect which produced them. When spring is well advanced the eggs hatch, and the tiny nymphs crawl out and migrate over the plant; in a few hours they settle down, insert their mouthparts, and begin sucking sap. At the first ecdysis the legs and antennae are shed, and the molt skin is incorporated in the scale covering formed over the body. By mid-August nymphal

Fig. 331. Scurfy scale, (left) oystershell scale, (center) and San Jose scale, (right). (Pettit, Mich. Agr. Exp. Sta.)

development is completed; the two-winged males emerge and mate with the females, which soon deposit the overwintering eggs. The shrivelled body of the female may be found beneath the anterior end of the scale. One generation is produced each year in the North, and two in the southern half of the country.

Natural control results mainly from numerous parasitic wasps, predatory lady beetles, and mites. Where feasible, pruning infested plant parts and destroying them in the winter will contribute to control.

The dormant oil emulsions recommended for San Jose scale will control this insect. Good control has been obtained by applying DDT just as the eggs are hatching. Use 2 pounds of 50% wettable powder or 2 quarts of 25% emulsifiable concentrate in 100 gallons of water. Either parathion or malathion may be applied at any stage of scale development but are especially effective when the eggs are hatching. Apply 1.5 to 2 pounds of 15% parathion wettable powder, 2 pounds of 50% malathion wettable powder, or 1 quart of 50% malathion emulsifiable concentrate, each in 100 gallons of water. Combinations of DDT and malathion have also been used with success.

Reference: *Ohio Biol. Survey Bul.* Vol. II, No. 2, 1963.

SCURFY SCALE

Chionaspis furfura **(Fitch), FAMILY DIASPIDIDAE**

This native insect is widely distributed in North America. It may attack a great number of shade trees, bush fruits, apple, pear, and quince, but it is not considered a serious pest. Damage from these piercing-sucking insects results in blemished fruits, reduced vigor of the plant, and sometimes death of heavily infested branches.

Except for the brown anterior tip, the scale covering of the female is white in sheltered situations, gray where exposed, more or less pear-shaped, and nearly $\frac{1}{10}$ inch in length (Fig. 332). The males are also white, much smaller, and parallel-sided with three dorsal ridges. The insect beneath the scale is yellow and rounded or elongate according to the sex.

Winter is passed as red-purple eggs under the scale coverings of females. Hatching takes place in April or May depending on the latitude, and in a few hours the crawlers settle and begin to feed. Like other armored scales, they lose their legs and antennae after the first molt and soon secrete the scale covering. When fully grown the two-winged males emerge, mate with the females, and die shortly afterwards. The females deposit their eggs under the scale coverings and then die. In the more northern range there is only one generation each year, but in North Carolina there are two complete generations.

Many of the parasites and predators that attack oystershell scale will

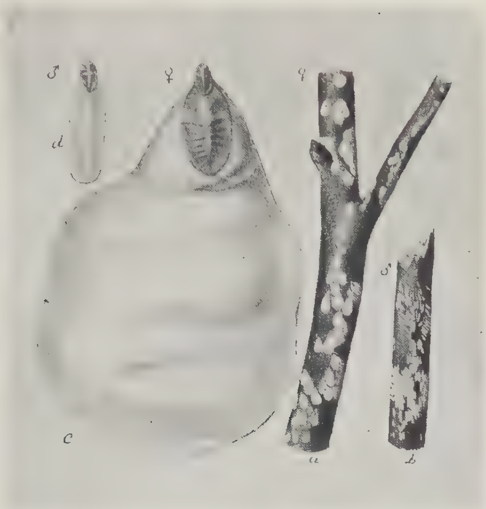


Fig. 332. The scurfy scale, *Chionaspis furfura* (Fitch): *a, c,* females; *b, d,* males. (Howard, U.S.D.A).

check scurfy scale. Usually this insect is not a problem in orchards regularly sprayed for control of San Jose scale. If scurfy scale becomes a problem in any habitat, the same insecticides recommended for oystershell scale will control it.

References: *J. Econ. Ent.*, 46:969–972, 1953; *Va. Poly. Inst. Tech. Bul.* 119, 1952.

OTHER ARMORED SCALES

Order Homoptera, Family Diaspididae

Forbes Scale, *Aspidiotus forbesi* Johnson, attacks cherry, apple, pear, peach, plum, quince, and currants. It is similar to San Jose scale but is a trifle larger and brown instead of dull black in the half-grown stage. The raised central point or nipple of the mature scale is orange instead of pale yellow, characteristic of San Jose scale. It winters as a partly grown scale in the North and as an adult female in the South. In the North, reproduction is said to be both oviparous and ovoviviparous; nymphs appear in May and June. In North Carolina, the young are born starting the last of May. There are one to three generations each year depending on the locality.

Putnam Scale, *Aspidiotus ancylus* (Putnam), resembles San Jose scale very closely, except that the female scale covering is a trifle larger and slightly darker, with the nipple brick red and off center. Winter is passed in the partly grown stage, and eggs are deposited in late spring. There is

only one generation per season. Apple and numerous shade and forest trees may be attacked.

European Fruit Scale, *Aspidiotus ostreaeformis* Curtis, is very similar to Forbes scale, and the two are usually confused. As the name suggests, this species was brought from Europe. It has been established in many localities, mainly in the northeastern parts of the country.

Howard Scale, *Abgrallaspis howardi* (Cockerell), is another relative of San Jose scale which is found primarily in the higher altitudes of Colorado, New Mexico, and adjoining states. It attacks all deciduous fruits and many ornamental plants, but pear seems to be the preferred host.

Walnut Scale, *Aspidiotus juglans-regiae* Comstock, is rather widely distributed and attacks many kinds of fruit and shade trees as well as ornamental plants. It is more abundant in the South than in northern regions. It is slightly larger than San Jose and Putnam scales, which it closely resembles in shape. Winter is passed as adult females beneath the gray-brown scale covering. The eggs are deposited in the spring. There are usually two generations each year.

Greedy Scale, *Hemiberlesia rapax* (Comstock), is a common species that attacks a wide range of hosts including citrus, deciduous fruits, and many ornamental trees and shrubs. It is generally more troublesome in Florida and California.

Oleander Scale, *Aspidiotus hederae* (Vallot), also called ivy scale, encrusts the leaves of English ivy, oleander, palms, and other semitropical plants. It is found in greenhouses in the North. The scale coverings are usually circular, the females being light buff with a tinge of purple and about three times the size of the males which are pure white.

Euonymus Scale, *Unaspis euonymi* (Comstock), attacks bittersweet, lilac, orange, and pachysandra, in addition to euonymus. The female scale resembles the female oystershell scale, and the male is white and narrow like the male of scurfy scale. Winter is passed as fully grown females under the scale covering. Pale yellow crawlers appear in May and June. There is a second and sometimes a third generation in some areas each season.

White Peach Scale, *Pseudaulacaspis pentagona* (Targ.), has been found in a number of localities but chiefly in the South. On peach trees it is sometimes as injurious as San Jose scale. It also attacks other stone fruits and grape. The females are circular and white tinged with brown. The males, which are usually found in groups, are elongated and pure white. There are four or five generations annually in the South. A 3% oil emulsion applied during the dormant period has successfully controlled this scale. Dormant-strength lime-sulfur has also been effective, sometimes two applications are required to clean up an infestation.

Control measures for these species of scales are approximately the same

as for San Jose and oystershell scales (p. 382). Where possible sanitation measures are of value in control. Ornamental plants are particularly adaptable to such control operations. Spraying with summer-type oils in the late dormant period is advised for tender foliage plants. Parathion and malathion can be applied at any time, but they are usually more effective when the crawler stages are present.

TERRAPIN SCALE

Lecanium nigrofasciatum Pergande, Family Coccidae

Terrapin scale is a soft or unarmored species; the protective covering is the thickened body wall itself rather than a separate structure. It is one of the largest native scales commonly found in orchards and is widely distributed over eastern United States and southern Canada. Many shade trees are also hosts of this species.

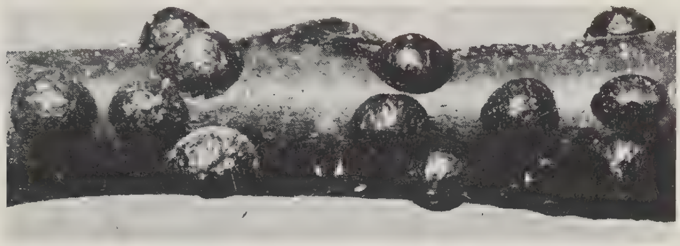


Fig. 333. The terrapin scale, *Lecanium nigrofasciatum* Pergande. (U.S.D.A.)

Adults are dark brown, sometimes with black banding and mottling, $\frac{1}{10}$ inch in length, very convex, hemispherical, and fluted or crimped near the edges of the body (Fig. 333). Early instars are much more flattened and lighter in color.

Only fertilized female scales survive the winter in the North. These deposit eggs in early summer which soon hatch into crawlers and migrate to the leaves, where they suck sap for nearly six weeks. The females then return to the twigs and branches where they continue their feeding and growth. The tiny, two-winged males are rarely seen but appear in late August and early September, effect fertilization, and die. The females continue feeding until cold weather; only one generation occurs each year. During feeding, especially in the later period, the scales excrete quantities of honeydew, which covers foliage and fruit, collects dust, and serves as a medium for the growth of sooty fungus. The presence of honeydew and attendant fungus growth on fruits greatly reduces its value.

Terrapin scale is partly controlled by its many natural enemies, some of

them of unusual interest. One is the larva of a pyralid moth, *Laetilia coccidivora* Comstock, which feeds as a predator on this and other scales. Another predator is the lady beetle, *Hyperaspus binotata* Say, the larvae of which live for a time in the cavity underneath the upper covering of the scale insect, later attacking and killing the developing young. Other species of lady beetles, aphid lions, and hemerobiids are also active predators. The most important parasites include *Aphycus stomachosus* Girault and several species of *Coccophagus.*

One recommended chemical control measure is a delayed dormant spray of 3 to 4% oil. Parathion, guthion, malathion, and carbaryl sprays have been found effective if applied as the crawlers appear in late spring or early summer.

References: *Conn. Agr. Exp. Sta. Bul.* 575, 1953; *U.S.D.A. Farmers' Bul.* 1861, 1954.

OTHER UNARMORED SCALES

Order Homoptera, Family Coccidae

European Fruit Lecanium, *Lecanium corni* Bouché, is widely distributed over the entire United States and southern Canada. It attacks numerous shade and forest trees as well as many fruit trees. The female is somewhat larger than that of the terrapin scale. Otherwise, the form, appearance, and life cycle are very similar. On some hosts the scale is partly covered with a white powdery substance. Control can be accomplished by the chemicals recommended for terrapin scale.

Cottony Peach Scale, *Pulvinaria amygdali* Cockerell, has been found as a pest in orchards in New York and Ontario; it apparently is of little importance elsewhere. It is a large species resembling those occurring on maple and grape. The eggs are deposited in a large, white cottony mass which protrudes from under the posterior part of the female scale insect. These eggs hatch into the crawler stage just before midsummer. A 3% oil emulsion applied as the buds are swelling has given good control. Parathion, guthion, carbaryl, or malathion are also effective in killing this scale, especially at the crawler stage.

Cottony Maple Scale, *Pulvinaria innumerabilis* (Rathvon), is a common and quite conspicuous pest of soft maple (Fig. 334). At times it is found

Fig. 334. Cottony maple scale. (Original.)

on other kinds of maples as well as a variety of other trees and shrubs. Heavy infestations excrete great quantities of honeydew, contaminating the foliage and objects below. Sooty fungus often develops on the honeydew covered leaves and branches.

Partly grown, brown, oval, female scales overwinter on the twigs and branches. Growth is rapid in the spring; this is followed by egg-laying in large cottony masses resembling popped corn. Hatching occurs in June and July, and the crawlers migrate to the leaves and suck sap. Maturity is reached in August; after mating the females crawl back to the twigs. Only one generation develops each year. Superior type oil emulsions in the dormant period and malathion or parathion summer sprays as the eggs hatch are the commonly recommended control chemicals.

Reference: *Ill. Nat. Hist. Sur. Cir.* 47, 1958.

PERIODICAL CICADA

Magicicada septendecim (L.), Family Cicadidae

The periodical cicada is one of the best-known insects within its range. It closely resembles the common or annual species seen every year, except for its smaller size, darker-colored body, orange wing veins, and red eyes. This cicada is mistakenly known as the seventeen-year locust. Some of its broods occur each year in the United States from the New England states to Texas.

Damage is caused by the females ovipositing in the twigs and branches of trees and shrubs. Branches having a diameter slightly larger than that of a pencil are most often attacked. A series of these oviposition wounds,

Fig. 335. Typical cicada injury. (W. E. Rumsey.)

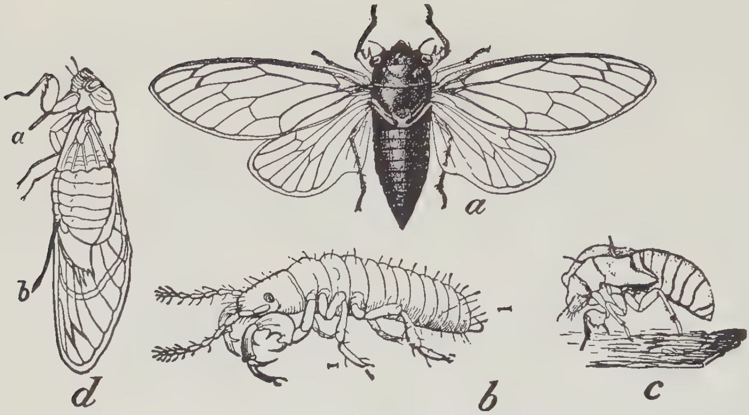


Fig. 336. Stages of the periodical cicada, *Magicicada septendecim* (L.): *a*, adult; *b*, young nymph, enlarged; *c*, cast skin of full-grown nymph; *d*, adult female, showing ovipositor at *b*, and beak at *a* (natural size). (Marlatt.)

often 3 to 4 inches in length, results in the weakening of twigs which may break off or, if this does not happen, are permanently scarred and abnormal (Fig. 335). Additional injury is caused by the removal of plant sap from the tree roots by the developing nymphal cicadas in the soil.

Adult cicadas begin emerging from the soil, usually late in May, and continue activity through a period of about six weeks. Individuals live almost a month, during which time very little nourishment is taken. Egg-laying begins approximately two weeks after emergence, and each female may deposit over 500 eggs. These are placed in the twigs in groups of fifteen or more. Hatching takes place nearly seven weeks later, and the nymphs drop to the ground, enter the soil, and begin feeding on root sap. This feeding continues for seventeen years in the North and thirteen years in the south. At the end of this prolonged growth period the nymphs (Fig. 336) make their way to the surface and emerge through holes almost 0.5 inch in diameter.

In moist soil the nymphs, before emerging, construct mud tubes extending up to 3 inches above the ground level. Great numbers emerge at the same time, starting at dusk. They crawl up on tree trunks or other objects in the vicinity and anchor their bodies. Several hours later the new adults emerge, expand their wings, and begin the short period of adult existence. The familiar song or call of the cicada is made only by the males and is produced by a pair of drumlike organs on the basal segments of the abdomen.

There are several broods of the periodical cicada, but the largest of all is brood *X*, which last occurred in 1953, and is due to appear again

in 1970. Many broods overlap in distribution. The race or variety that requires only thirteen years for its development is found primarily in the the southeastern states, but one brood extends into Illinois. The latter is generally distributed in the South and will appear again in 1972. A lighter and less extensive brood is due in scattered locations in the South in 1976. For convenience, the broods have been designated by Roman numerals. The numerals I through XVII are assigned to the seventeen-year broods, and XVIII through XXX to the thirteen-year broods.

When a large brood of cicadas is due to appear in any area it is well to defer planting young trees and shrubs until after this period is passed. It is also well to postpone pruning trees during the year before an outbreak so that injury may be distributed on a maximum number of twigs. The worst of these may be removed by pruning the following winter, and enough may escape serious injury so that the tree will not be permanently deformed. Where feasible, valuable trees and shrubs may be protected by covering them with cheesecloth or similar material during the oviposition period.

Two or three night or early-morning spray applications about one week apart, using 0.5 pint of 40% tetraethyl pyrophosphate in 100 gallons of water, has given excellent control of adult cicadas. For maximum effect the first application should be made a few days before egg-laying begins. For most localities this would be one week after adult emergence begins. Where longer protection of plants is feasible and poisonous residues are not a problem, apply a spray containing 1 pound of carbaryl in 100 gallons of water. One quart of 26% emulsifiable demeton in 100 gallons of water has also given excellent kill of adult cicadas.

Natural enemies include birds, a fungus disease that kills some adults, and some insects and mites that attack the eggs.

References: *U.S.D.A. Bul.* 71, 1907; *Leaflet* 340, 1960; *Ohio Agr. Exp. Sta. Bul.* 311, 1917; *J. Econ. Ent.*, 42:359–362, 1949; 46:385, 1953; 50:713–715, 1957; 57:295, 1964.

TREEHOPPERS

Order Homoptera, Family Membracidae

Treehoppers of many species attack fruit and ornamental trees, as well as other woody plants. Some of those most frequently mentioned are the buffalo treehopper, *Stictocephala bubalis* (Fabr.); the green clover treehopper, *Stictocephala inermis* F.; the dark-colored treehopper, *Ceresa basalis* Walker; and the quince treehopper, *Glossonotus crataegi* (Fitch) (Figs. 337 and 338)). There are doubtless more important species found in other localities. The range of treehoppers is throughout the country, but certain species may be localized in given regions.

Injury is due almost entirely to the twig punctures that the females

Fig. 337. The buffalo treehopper. (U.S.D.A.)

Fig. 338. (Left) the buffalo treehopper, *Stictocephala bubalis* (Fitch); (center) *Stictocephala inermis* F.; and (right) *Ceresa basalis* Walker. (U.S.D.A.)

make in ovipositing. These may be severe to young trees and to new growth in older trees. Treehoppers, especially the nymphs, also cause damage to clovers, alfalfa, corn, and other plants by sucking sap. They are most likely to be injurious to trees where the orchard is adjacent to a legume crop or has a legume ground cover.

Since most treehoppers are considered secondary pests and since the

injury from various species is similar in character, no attempt will be made to give separate life cycles. The winter is passed as eggs in the twigs from which the nymphs hatch in April or May. These drop to the ground and feed on the cover crop, becoming adults in July. Oviposition takes place in August, usually in the current and previous season's wood.

Injury can be largely prevented by clean cultivation, but this is often undesirable especially in older orchards. Avoiding cover crops of alfalfa or clovers is also a desirable practice where treehoppers are causing damage. A thorough application of 4% dormant oil kills most of the eggs in the twigs. Successful control has been accomplished by applying DDT or parathion in July before the adults begin egg-laying, with part of the spray directed to the ground cover.

References: *U.S.D.A. Cir.* 270, 1950; *Agr. Handbook* 290, 1965; *Conn. Agr. Exp. Sta. Bul.* 552, 1952.

BAGWORM

Thyridopteryx ephemeraeformis (Haworth), **Family Psychidae**

Bagworms produce the conspicuous, spindle-shaped cocoons or cases which are familiar objects on trees and shrubs throughout the United States east of the Rocky Mountains (Fig. 339). These caterpillars devour the foliage of a large variety of fruit and shade trees as well as ornamental shrubs, particularly junipers and arbor vitae; then they are often called evergreen bagworms.

Overwintering, light tan eggs inside the bags begin hatching in June into dark brown larvae, which start to feed and immediately to construct the case or bag. This bag is carried around by the larva and enlarged as development proceeds; when full growth is attained it is attached to a twig or small branch with a band of silk. Pupation occurs in early September; several days later the adult winged males (Fig. 340) emerge and fly to the bags containing wingless females, and mate with them at the lower tip of the case. The male moth is almost black, with four transparent

Fig. 339. Cocoons of the bagworm.

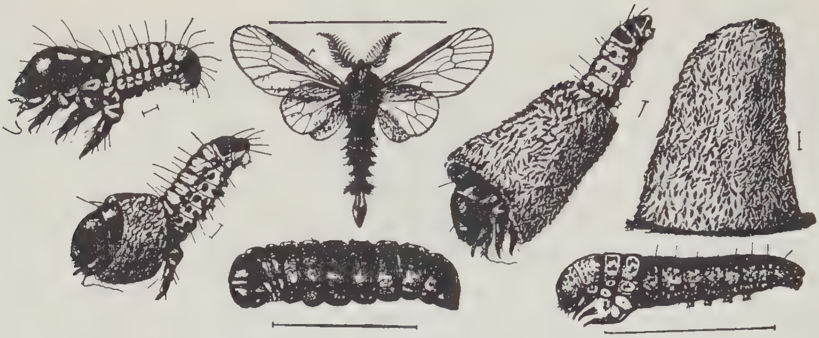


Fig. 340. The bagworm, *Thyridopteryx ephemeraeformis* (Haworth). Note early stages of the formation of the bag, the winged male, and wingless female. (Riley.)

wings practically free of scales. It is seldom seen during its short life in late summer. After mating, the female moths deposit their eggs in the old pupal case and die. There is usually only one generation each year.

Clipping the bags from small shrubs during the winter and destroying them gives complete control. Choice plants of juniper and arbor vitae should have all bagworm cases removed during the winter including the silken band around the twig, to prevent disfiguration by girdling. A thorough spraying with 4 pounds of lead arsenate to 100 gallons of water in late June will kill the larvae. Timing of the application is important; later spraying requires an increase in the dosage. In addition sprays containing Zectran, carbaryl, dieldrin, diazinon, malathion, naled, or toxaphene have been effective in controlling this pest. Populations of this insect vary greatly from year to year because there is an unusually high degree of natural control from parasites.

References: *U.S.D.A. Farmers' Bul.* 701, 1916; *Tex. Agr. Exp. Sta. Bul.* 382, 1928; *J. Econ. Ent.*, 51:367–368, 1958; 52:353, 1959; 57:176, 769, 1964.

CANKERWORMS

Order Lepidoptera, Family Geometridae

Cankerworms devour the foliage of many forest, shade, and fruit trees. Apple and elm species are the most common hosts. Repeated defoliation weakens the trees, making them susceptible to attacks of other insect pests. The larvae are known as measuring worms, inchworms, or loopers because of their habit of arching their bodies high in the center while in the act of crawling. Sometimes they spin silken threads on which they may be seen crawling or swinging.

The fall cankerworm, *Alsophila pometaria* (Harris), occurs in the area from Nova Scotia to North Carolina, west to Missouri, northwest to Mon-

tana and Manitoba. It is also found in Colorado, Utah, and California. Most adult moths emerge in November and early December, although some continue to appear during warm periods in the winter. Each female deposits gray-brown eggs in compact masses of about 100. These are placed on twigs and branches of trees. Hatching occurs as soon as the foliage begins to appear in the spring, and the young larvae feed on the leaves for a period of three or four weeks, then drop to the ground and pupate in silken cocoons formed in the soil. There is only one generation per year.

The larvae are slender, striped, green, looping caterpillars, about 1 inch long, with three pairs of abdominal prolegs. The male moth is ash gray, with faint markings of both black and white, and a wingspread of 1 inch. The female is entirely wingless. The appearance of each stage is illustrated (Fig. 341).

The spring cankerworm, *Paleacrita vernata* (Peck.), has the same general distribution as that of the fall species, except that its range extends farther south, especially in the plains region, where it reaches northern Texas. It also occurs in California. Adult moths emerge in February, March, or April, and deposit their dull-colored oval eggs in loose irregular clusters of about fifty. The eggs are usually laid under bark scales, crevices, and other secluded places. Hatching and larval development occur at the same time as for the fall species, but no cocoon is formed by the spring species before pupation in the soil. Only one generation develops each season.

The slender larvae are light green to brown or black, with white lines down the back. Only two pairs of abdominal prolegs are present. Adults are very similar, except that the female of the spring species has double rows of red spines across the abdominal segments (Fig. 342), whereas the female of the fall species is spineless. Cankerworms are normally kept under control by natural forces, consisting of many predatory and parasitic enemies and climatic factors.

Sticky tree bands placed on tree trunks in early October capture many adult female, fall cankerworms. These bands must be renewed in late February to capture the adult female, spring cankerworms. The bands are constructed of a strip of cheap cotton batting 2 inches wide, placed around the tree trunk and covered with a strip of single-ply tarred paper 5 inches wide, which is tacked securely. The tarred paper is then covered with the sticky tree-banding substance.

Cankerworms are not pests of fruit trees where a spraying program is followed. Therefore they are a problem only on ornamental trees or in forested areas. Control may be readily accomplished by spraying soon after the eggs hatch, with 3 pounds of lead arsenate plus a commercial

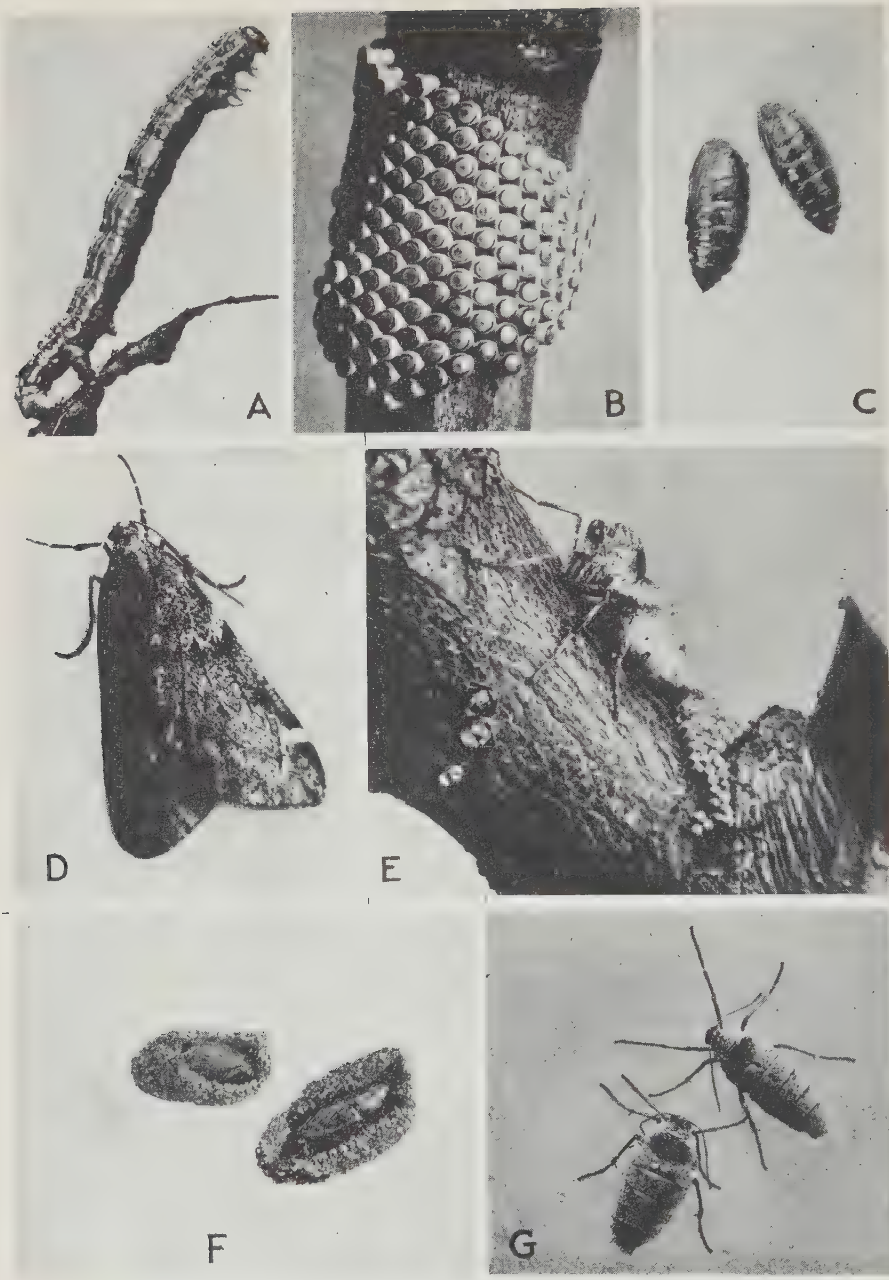


Fig. 341. The fall cankerworm, *Alsophila pometaria* (Harris), showing several developmental stages: *A*, full-grown larva ($\times 2\frac{1}{2}$); *B*, egg mass ($\times 7$); *C*. pupae ($\times 2\frac{1}{4}$); *D*, male moth ($\times 3$); *E*, female moth laying eggs ($\times 3$); *F*, pupae in cocoons ($\times 1\frac{3}{4}$); *G*, female moths ($\times 2\frac{1}{4}$). (Porter and Alden, U. S. D. A.)

Fig. 342. The spring cankerworm, *Paleacrita vernata* (Peck); male and female moths, eggs, and a larva. (Porter and Alden, U.S.D.A.)

sticker-spreader in 100 gallons of water. DDT is also effective, and 2 quarts of 25% emulsifiable concentrate, or 2 pounds of 50% wettable powder in 100 gallons of water, is recommended in hydraulic sprayers. Forested areas may be treated by means of an airplane using 1 pound of DDT per acre. Other control chemicals are carbaryl, diazinon, and Zectran.

References: *U.S.D.A. Bul.* 1238, 1924; *Leaflet* 183, 1953; *Conn. Agr. Exp. Sta. Cir.* 214, 1960.

EASTERN TENT CATERPILLAR

Malacosoma americanum (F.), Family Lasiocampidae

Widely distributed throughout the United States east of the Rocky Mountains, and similar to other defoliating caterpillars, this insect may become a problem in neglected orchards, and on shade or forest trees, but it is unimportant where spraying is regularly practiced. Apple and wild cherry are the most common hosts.

Dark brown masses of eggs which encircle the twigs are the overwintering stage. Embryonic development starts immediately after deposition and within a month the eggs contain fully formed larvae. Each mass may contain 150 to 350 eggs. Hatching takes place about the time that new leaves on wild cherry trees begin to appear in the spring. The larvae are gregarious and soon construct a tent of silk in a crotch of the tree, enlarging it as they grow. During cloudy and rainy weather the larvae remain within the tent, but when the weather is favorable they emerge onto the foliage and feed at regular intervals, spinning threads of silk wherever they crawl. About six weeks after hatching, the characteristically marked larvae become fully grown, reaching a length of 2 or more inches. Pupation occurs in silken cocoons, which are found on tree trunks, fences, leaf litter, or debris on the ground. Some two weeks later emergence of the red-brown moths with diagonal white stripes takes place and depo-

Fig. 343. Adults of the tent caterpillar, *Malacosoma americanum* (F.). (U.S.D.A.)

sition of the overwintering eggs soon follows, after which the moths die. (See Figs. 343, 344, 345, 347, 348.)

Tent caterpillar populations fluctuate greatly because of control by natural enemies, some of which are birds, predaceous and parasitic insects, and disease organisms. Unfavorable weather also acts as a natural check on this insect.

Collecting and destroying egg masses during the winter is sometimes suggested as a means of control on a small scale. The most efficient method for eliminating the caterpillars is to spray when they appear with 4 pounds of lead arsenate or 2 pounds of 50% DDT wettable powder in 100 gallons of water. Other control chemicals are carbaryl, diazinon, malathion, methoxychlor, and toxaphene.

References: *U.S.D.A. Leaflet* 161, 1958; *Misc. Pub.* 657:416–417, 1950; *Agr. Handbook* 290, 1965.

FOREST TENT CATERPILLAR

Malacosoma disstria Hübner, Family Lasiocampidae

This species is a widespread defoliator of deciduous forest and shade trees throughout Canada and the United States from Minnesota eastward. Serious outbreaks often persist for three or more years before natural factors bring the pest under control. Heavy damage has been wrought in Canada, the New England states, New York, Minnesota, Michigan, Mississippi, and Louisiana.

The life cycle is essentially the same as that of the eastern tent caterpillar. Adult moths are light buff-brown, with a wing expanse of 1 to $1\frac{1}{2}$ inches, the fore wings having two darker, oblique lines near the middle. The egg mass encircles the twig and contains up to 350 eggs cemented together with a dark varnish-like substance. Fully grown larvae are about 2 inches long, dark in color with a row of white spots along the back

Fig. 344. Tent caterpillars, *Malacosoma americanum* (F.).

Fig. 345. Eggs of the tent caterpillar.

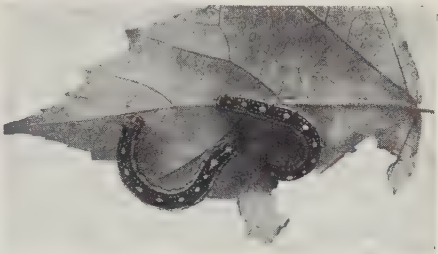


Fig. 346. Forest tent caterpillars. (Britton.)

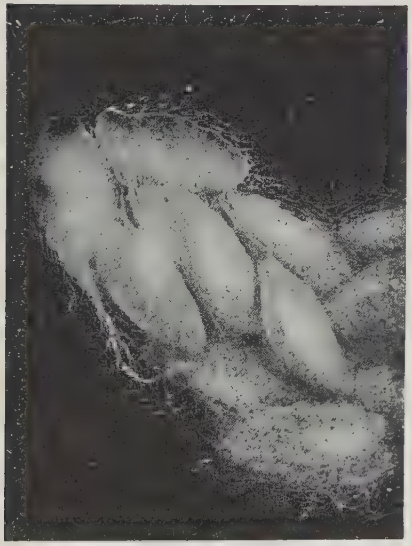


Fig. 347. Cocoons of the tent caterpillar; natural size. (Lowe.)

Fig. 348. Newly formed tent of eastern tent caterpillar.

(Fig. 346). These larvae are gregarious until they are nearly full size, and instead of a tent they make a silken mat on the trunk or branch where they congregate after feeding or during molting. Pupation takes place inside silken cocoons on tree trunks or other objects near-by; approximately two weeks later the adults emerge. After mating, the eggs are deposited which become the overwintering life stage. Embryonic development begins immediately after egg deposition and in about thirty days they contain fully formed larvae. Only one generation develops each year.

Control measures are the same as those suggested for the eastern tent caterpillar.

References: *U.S.D.A. Misc. Pub.* 657:418–419, 1950; *J. Econ. Ent.*, 57:157–160, 1964.

FALL WEBWORM

Hyphantria cunea (Drury), Family Arctiidae

Distributed throughout the greater part of the United States and Canada, this caterpillar is a general feeder on deciduous trees and shrubs. It is often seen on roadside trees and in neglected orchards. Besides defoliation the larvae produce large unsightly webs on the branches (Fig. 349). There are two distinct forms or races of this insect in Louisiana.

The moth is pure white, with a wing expanse of $1\frac{1}{4}$ inches, the fore wings

Fig. 349. Web of the fall webworm, *Hyphantria cunea* (Drury).

sometimes marked with black dots. These adults emerge from overwintering pupae in May to July, depending on the climate, and lay masses of 400 to 900 white eggs usually on the undersides of the leaves. In a few days hatching occurs, and the larvae begin to spin silken webs over the foliage, extending them as the enclosed leaves are devoured. The hairy light tan larvae are gregarious until the last instar, after which they may be found crawling any place on the host plants. They are nearly 1 inch in length at this stage of development. Pupation takes place in a silken cocoon among debris on the ground. Generally, the larvae of the first generation are active in June and July; the larvae of the second generation are active in August and September. Where a single generation occurs larval activity is usually from July to September.

A number of natural enemies keep the fall webworm in check but in some years it becomes quite abundant. Pruning and destroying the larval webs as soon as they are discovered are often practical control measures. Spraying with 3 pounds of lead arsenate or 2 pounds of 50% DDT wettable powder in 100 gallons of water, just as new webs appear, is also a recommended practice. Orchards in which a spray schedule is followed are not troubled by fall webworms.

References: *U.S.D.A. Misc. Pub.* 657:387–388, 1950; *Conn. Agr. Exp. Sta. Bul.* 203, 1918; *Ann. Ent. Soc. Amer.*, 57:192–194, 1964; *J. Econ. Ent.*, 57:314–318, 1964.

WHITE-MARKED TUSSOCK MOTH

***Hemerocampa leucostigma* (Smith), Family Liparidae**

This species occurs in eastern United States and Canada, and west into Colorado and British Columbia. It is a general feeder on foliage of deciduous trees and shrubs, particularly apple, basswood, elm, poplars, rose, sycamore, willow, wisteria, and Norway, silver, and sycamore maples.

The male moth is ash gray with feathery antennae and a wingspread of about $1\frac{1}{4}$ inches. The fore wings have wavy bands of a darker shade. All females are wingless and white- or gray-colored. They deposit their eggs in white masses cemented to the surface of the old cocoons; the winter is passed in this way. Hatching takes place between April and June, depending on the latitude, and the larvae become fully grown in thirty to forty days. At that time they are nearly $1\frac{1}{4}$ inches long, slender, cream yellow, with a broad, black longitudinal stripe on the back and a broader gray one on each side. The head is red and the body is ornamented by two tufts of long black hairs on the prothorax, another black tuft on the eighth abdominal segment, four brushlike tufts of light tan hairs on each of the first four abdominal segments, and red dots on the sixth and seventh abdominal segments (Fig. 350). Pupation takes place in cocoons made of silk and old larval hairs. These cocoons may be found

Fig. 350. The white-marked tussock moth, *Hemerocampa leucostigma* (Smith). (Ohio Agr. Exp. Sta.)

on the tree trunk, on branches, or on other objects near infested trees. In two weeks the new adults emerge, mate, and soon afterwards deposit eggs. There are three generations per year in the latitude of Washington, D.C., and one in the latitude of northern New York.

In some areas, other species of tussock moths may be more abundant than the one under consideration.

Tussock moth larvae and eggs are attacked by many natural enemies. Those of greatest importance are insect parasites and predators, birds, and wilt disease. Daubing the egg masses during the winter with creosote or oil is sometimes suggested as a control measure. The best way to eliminate a larval population is to spray with 4 pounds of lead arsenate or 2 pounds of 50% DDT wettable powder in 100 gallons of water.

References: *Ohio Agr. Exp. Sta. Bul.* 332, 1918; *Ill. Nat. Hist. Sur. Cir.* 47, 1958.

GYPSY MOTH

Porthetria dispar (L.), Family Liparidae

The gypsy moth was accidentally liberated in Massachusetts in 1868, having been brought from Europe for experiments in silk production. It has since spread to the states of Maine, New Hampshire, Vermont, Rhode Island, Connecticut, and adjacent areas of Pennsylvania, New Jersey, New York, and southeastern Canada. Several local infestations have been eradicated, and because of federal and state quarantines the infested area is still confined to parts of the New England states.

Damage results from the caterpillars devouring the foliage of shrubs, fruit, shade, and forest trees, including conifers. It is more important as a pest of forests than of orchards, but it may be very destructive in neglected orchards.

The adults are shown in Fig. 351; the male is slightly smaller and darker in color. Although both sexes are winged, only the male can fly.

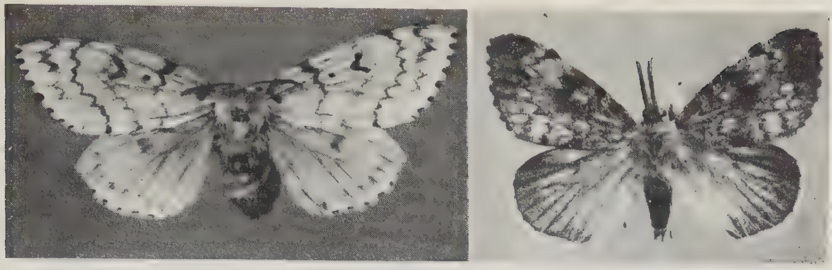


Fig. 351. The gypsy moth, *Porthetria dispar* (L.); (left) female, (right) male. (U.S.D.A.)

Fig. 352. Larvae and egg mass of the gypsy moth.

After emergence and mating, the female crawls up some nearby object, usually the tree trunk or branches, and deposits masses of eggs, each containing four hundred or more (Fig. 352). The eggs are packed with tan hairs from her body. Mature larvae are nearly $2\frac{1}{2}$ inches long; the head has yellow markings, the body is dusky and hairy, with a double row of five pairs of blue tubercles followed by six pairs of red tubercles on the dorsal side. The diagrammatic representation of the life cycle gives all the essential information concerning developmental activity (Fig. 356). There is only one generation per year.

They are spread from one area to another primarily by shipment or movement of infested nursery stock or commercial products on which eggs may be deposited. When the first instar larvae spin down on silken threads, they may be transported by man or borne long distances by the wind.

Natural and biological control agents check the ravages of this pest. One predator, a ground beetle closely related to several native species, *Calosoma sycophanta* (L.), was brought from Europe and has become permanently established and of definite value. Larval and pupal parasites of

proven value are the tachinid flies, *Compsilura concinnata* (Meigen) and *Blepharipa scutellata* (Rob.-Desv.), and the braconid wasp, *Apanteles melanoscelus* (Ratz.). Egg parasites of importance are *Anastatus disparis* Ruschka and *Ooencyrtus kuwanai* (Howard). Other established parasites of some value in control are *Apanteles lacteicolor* Vier., *Phobocampe disparis* (Vier.), *Monodontomeris aereus* Walker, and *Parasetigena agilis* (Rob.-Desv.). A "wilt" or polyhedral virus disease as well as climatic factors and insectivorous birds also help to prevent serious outbreaks.

Developing stands of trees somewhat resistant to gypsy moth attack, by reducing the proportion of favored host species such as basswood, hawthorn, oaks, poplars, willows, and gray and river birch, is of value in forested areas. Egg clusters can be destroyed by saturating them with a commercial creosote mixture. Spraying infested trees with 5 to 10 pounds of lead arsenate plus 1 pint of fish oil or linseed oil to 100 gallons of water has been a standard chemical control measure. DDT is now widely employed for both ground and aerial application because it is more effective and cheaper. Emulsion or wettable powder sprays have given control at 1 pound of actual DDT per acre. On occasion, particularly where a few ornamental shrubs or shade trees are concerned, a band of burlap may be tied around the tree trunk and folded down at the middle. This affords shelter for the larvae in the daytime. These bands should be examined frequently and the larvae destroyed. Gyplure, the synthetic form of the sex lure found in unmated female gypsy moths, may find a place in the control program. By using this lure all males might be caught in traps or poisoned by baits and reproduction of the species halted because all eggs are sterile.

References: *U.S.D.A. Cir.* 464, 1938; E–726, 1947; *Misc. Pub.*, 657:408–412, 1950; *Conn. Cir.* 186, 1954; *Bul.* 655, 1963; *Pa. Dept. Agr. Misc. Bul.* 4404, 1962.

BROWN-TAIL MOTH

Nygmia phaeorrhoea (Donovan), Family Liparidae

The first record of the brown-tail moth in the United States was in Somerville, Massachusetts, in 1897, but actual introduction probably took place several years earlier. Later it became established in the eastern part of Connecticut and Vermont, in New Hampshire, Maine, and the provinces of New Brunswick and Nova Scotia. In recent years the most serious infestations have been confined to the southeastern part of Maine, the southern half of New Hampshire, and the eastern part of Massachusetts.

The larvae most often devour the foliage of pear, apple, plum, cherry, hawthorn, white oak, rose, and willow, but occasionally other deciduous trees are attacked.

As illustrated (Fig. 353) the moths are white, with the abdomen densely clothed with brown hairs, especially at the tip. The females have a wing

Fig. 353. Male and female brown-tail moths. (U.S.D.A.)

Fig. 354. Larvae of brown-tail moth and egg mass on leaf. (U.S.D.A.)

expanse of about $1\frac{1}{2}$ inches; the males are slightly smaller. The eggs are usually deposited on the underside of a leaf in masses, each containing almost 300. They are closely packed and covered with brown hairs (Fig. 354). Fully grown larvae are nearly $1\frac{1}{2}$ inches long, the head is light brown, the body dark brown to black, with a broken white line on each side and two conspicuous red spots near the posterior end. The larvae possess

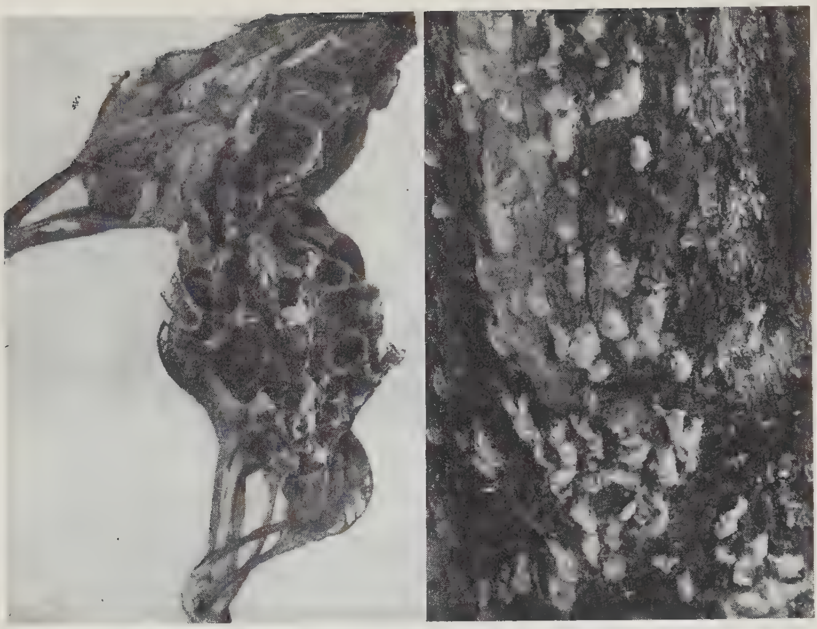


Fig. 355. (Left) winter nest of brown-tail moth; (right) egg masses of the gypsy moth on tree trunk. (U.S.D.A.)

numerous hairs which are irritating to the skin of persons on whom they might chance to lodge, either from handling or from those floating in the air during the larval molting periods. Avoid breathing the hairs into the lungs.

There is one generation annually in the New England states. The essential difference in the life cycle of this insect and of the gypsy moth is that the eggs of the brown-tail moth hatch the same summer they are laid, the larvae feed for a short time in August or early September, then form shelters of silk spun about leaf clusters at the tips of twigs, in which they hibernate during the winter (Fig. 355). The complete life cycle is shown (Fig. 356) for comparison with that of the gypsy moth.

Federal quarantines regulating the shipments of nursery stock, eradication programs carried on by the federal, state, and municipal governments, and the introduction and establishment of parasites have greatly reduced infestations of the brown-tail moth and thus prevented widespread dispersal.

Low winter temperature plays an important part in the control of this pest. In addition, the parasites *Compsilura concinnata* (Meigen), *Townsendiellomyia nidicola* (Townsend), *Carcelia laxifrons* Vill., *Meteorus versicolor* (Wesm.), and *Apanteles lacteicolor* Vier. are also effective enemies,

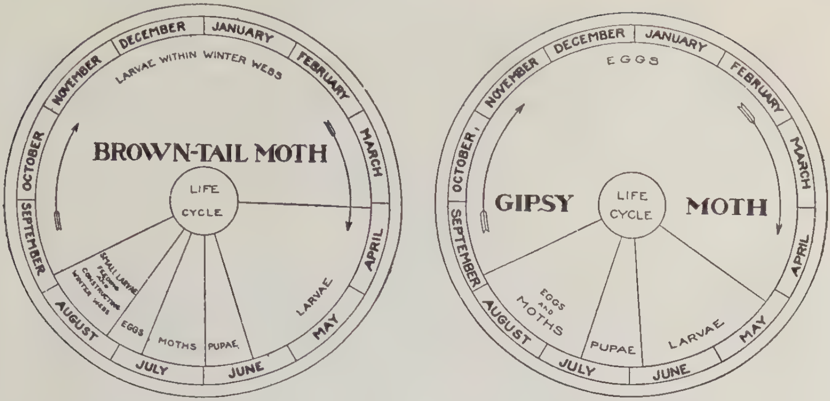


Fig. 356. Diagrams showing the life cycle of the brown-tail moth and of the gypsy moth. (U.S.D.A.)

along with the predator, *Calosoma sycophanta* (L.). A fungus disease, *Entomophthora aulicae* (Reich.), greatly reduces a larval population when weather conditions favor it.

Chemical control consists of spraying with DDT or lead arsenate, as recommended for the gypsy moth (p. 404). Fruit orchards given a regular spray program are not troubled with brown-tail moth. Collection and destruction of the larval nests or hibernacula in the winter greatly reduces a population, especially if practiced on a community-wide basis.

References: *U.S.D.A. Cir.* 464, 1938; *Misc. Pub.*, 657:412–414, 1950; *PA* 282, 1956.

RED-HUMPED CATERPILLAR

Schizura concinna (Smith), Family Notodontidae

This species is widely distributed from Canada to the Gulf and from the Atlantic to the Pacific. The larvae commonly feed on apple, elm, poplar, rose, plum, willow, walnut, wild black cherry, and other deciduous trees. Small larvae skeletonize the leaves; the larger ones devour all but the midrib. They are locally abundant in unsprayed apple orchards, nurseries, or on ornamental shade trees.

The adult is a gray-brown moth with a wing expanse of slightly more than 1 inch. Fully grown larvae are over an inch in length and strikingly colored. The head is coral red, the body marked with black and yellow lines, and on the first abdominal segment is a conspicuous red hump (Fig. 357). The tip of the abdomen is usually held in an elevated position.

Winter is passed as fully grown larvae inside silken cocoons in the duff on the ground. Pupation takes place in the spring and adults emerge from late May to July. The eggs are white and deposited on the undersides of

Fig. 357. The red-humped caterpillar, *Schizura concinna* (Smith).

the leaves in masses of 100 or less. On hatching, the caterpillars feed in groups, often defoliating a single branch. Full growth is attained in three or more weeks, and transformation to pupae takes place, with new adults appearing in July and August. Two or more generations develop in warmer areas; only one occurs in their northern range.

Clipping off and destroying infested branches controls the insect and is a recommended practice where only a few plants are involved. Apple orchards receiving a regular spray program are not troubled with this insect. When a destructive population develops in young orchards, nurseries, or on shade trees, spray thoroughly with 3 pounds of lead arsenate to 100 gallons of water. DDT, malathion, and parathion are also recommended control chemicals.

YELLOW-NECKED CATERPILLAR

Datana ministra **(Drury), Family Notodontidae**

This species occurs throughout most of the United States and southern Canada. Its food plants include apple, birch, blueberry, basswood, cherry, elm, hawthorn, oak, and other deciduous trees. Often it is locally abundant, particularly on unsprayed apple trees. Injury results when the larvae devour the foliage.

The yellow-and-black-striped caterpillars reach a length of 2 inches

when fully grown and have a prominent yellow spot just back of the head. When disturbed they raise their head and tip of abdomen in an upright position and cling to the twig or branch by four of their five pairs of abdominal prolegs (Fig. 358). They are gregarious in habit and tend to congregate in crotches of larger branches at the molting periods (Fig. 359). The adults have cinnamon brown front wings, each crossed by four

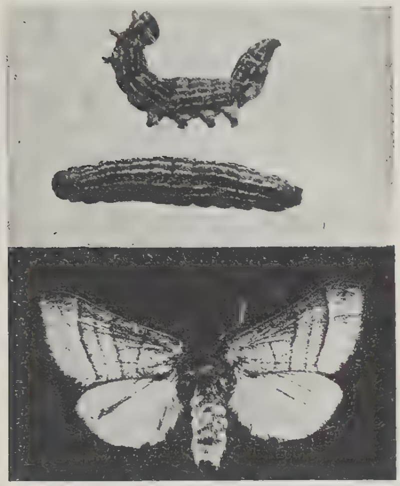


Fig. 358. The yellow-necked caterpillar, *Datana ministra* (Drury); larvae and moth.

Fig. 359. Characteristic cluster of yellow-necked caterpillars.

darker lines; the hind wings are light buff (Fig. 358). They have a wing expanse of nearly 2 inches.

Winter is passed as brown pupae in the soil. Adults appear during June and July, and lay white eggs on the leaves in masses containing up to one hundred. The caterpillars may be found from late June to October in some regions, but development is normally completed in three or four weeks when they enter the soil and change to pupae. One generation per year is the usual number.

The simplest method of control in light infestations is by removing and destroying each colony of caterpillars. In heavier infestations apply a spray containing 3 pounds of lead arsenate or 2 pounds of 50% DDT wettable powder in each 100 gallons of water. Apple orchards receiving a regular spray program are never troubled by this insect. Other useful insecticides are malathion and parathion.

WALNUT CATERPILLAR

Datana integerrima G. and R., Family Notodontidae

A close relative of *D. ministra,* this caterpillar is found throughout most of eastern United States west to Kansas. Its food plants are butternut, walnut, hickory, and pecan. When this insect becomes abundant the trees may be completely defoliated.

The fully grown larvae are almost 2 inches long, black and clothed in long gray hairs. Younger instars are nearly naked and vary from brick red to dark red-brown with pale yellow-to-gray longitudinal stripes. When disturbed they raise their head and tip of abdomen in an upright position, and hold to the twig or branch with four of their five pairs of abdominal prolegs. They are also gregarious in habit, feeding together and congregating in large masses on the tree trunk during the molting periods. The adults closely resemble *D. ministra.*

The life cycle is also the same as that of the yellow-necked caterpillar. However, in the South there are two generations, the first brood of larvae appearing in June and July, and the second in August and September.

Light infestations on small trees can be eliminated by crushing or burning the masses of larvae. Larger trees must be sprayed with arsenical, DDT, or parathion. Use 3 pounds of lead arsenate, 2 pounds of 50% DDT, or malathion, or 15% parathion wettable powder per 100 gallons of water. Applications should be made when the caterpillars are small.

References: *Ohio Agr. Exp. Sta. Bul.* 332, 1918; *U.S.D.A. Farmers' Bul.* 1829, 1954; *Agr. Handbook* 240, 1963.

ELM LEAF BEETLE

Pyrrhalta luteola (Müller), Family Chrysomelidae

The elm leaf beetle may be found nearly every place that elm trees grow in North America. Larvae devour the lower surface of the leaves causing them to dry up and drop prematurely. Adults eat small holes in the leaves. Heavy defoliation weakens the trees and makes them subject to the attacks of bark beetles and borers, as well as disease organisms. Elms growing in urban areas are most heavily attacked.

The adult beetle is $\frac{1}{4}$ inch long, varying from yellow when young to olive green when aged, with a black stripe along the margin of each wing cover. The eyes are black; the legs and antennae are yellow. These beetles pass the winter in secluded places, often in buildings and under plant debris. They emerge in the spring and fly to elm trees with unfolding leaves where feeding takes place, followed by oviposition. The yellow eggs are placed in groups of five to twenty-five on the undersides of the leaves, each female laying over 400. Hatching occurs in about a week, and the

dull yellow larvae with two dark stripes and black tubercles skeletonize the leaves. In almost three weeks they are fully grown, attaining a length of $\frac{1}{2}$ inch. Pupation then follows in crotches or crevices in the bark or on the ground. In approximately ten days the new adults (Fig. 360) emerge from the bright yellow pupae. There are two generations per year in the latitude of Columbus, Ohio, but in more southern areas there may be a partial third generation.

Natural enemies include birds, toads, diseases, and predaceous and parasitic insects. A chalcid wasp, *Tetrastichus brevistigma* Gahan, frequently kills many pupae. The fungus, *Beauveria globulifera* (Speg.), also kills pupae and adults late in the summer, especially in humid seasons.

Chemical control is accomplished by spraying with 4 pounds of lead arsenate plus 2 pounds of wheat flour per 100 gallons of water. DDT is also effective but favors the development of spider mites. Use 1 pound of 50% DDT wettable powder or 1 quart of 25% emulsifiable concentrate per 100 gallons of water. Application should be made as the eggs are hatching, usually the latter part of May. If a thorough job of spraying is done at that time usually nothing need be applied for later generations. Larvae migrating on the tree trunk before pupation may also be killed with DDT.

References: *U.S.D.A. Leaflet* 184, 1952; *Ill. Nat. Hist. Sur. Cir.* 47, 1958.

ELM BARK BEETLES

Order Coleoptera, Family Scolytidae

Two kinds of bark beetles commonly attack elm trees in Canada and the United States. One is the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), and the other the native elm bark beetle, *Hylurgopinus rufipes* (Eichh.). So far as is known, these bark beetles attack only elm and are important pests principally because they spread the fungus causing Dutch elm disease.

Native to Europe, the smaller European elm bark beetle was found in the vicinity of Boston, Massachusetts, as early as 1904. Since then it has been found in most of the states east of the Rocky Mountains, in California, Oregon, and the bordering provinces of Canada from Ontario to Quebec. It undoubtedly will spread throughout the natural range of the elm tree.

The adult is a shiny, dark red-brown beetle, approximately $\frac{1}{8}$ inch long; the underside of the posterior end of the body is concave with a prominent spine. These adults appear in the spring about the middle of May, emerging from holes they make in the bark. They feed in the crotches of living elm twigs and, if carrying the Dutch elm disease fungus, may introduce these organisms into healthy trees. Later they bore through the bark of recently cut, dead, or dying trees, forming galleries by grooving the surfaces of both

Fig. 360. The elm leaf beetle: *a*, adult and larval feeding damage; *b*, adult beetle; *c*, eggs; *d*, young larvae; *e*, mature larva; *f*, mouthparts of larva; g, pupa; all figures enlarged except *a*. (U.S.D.A.)

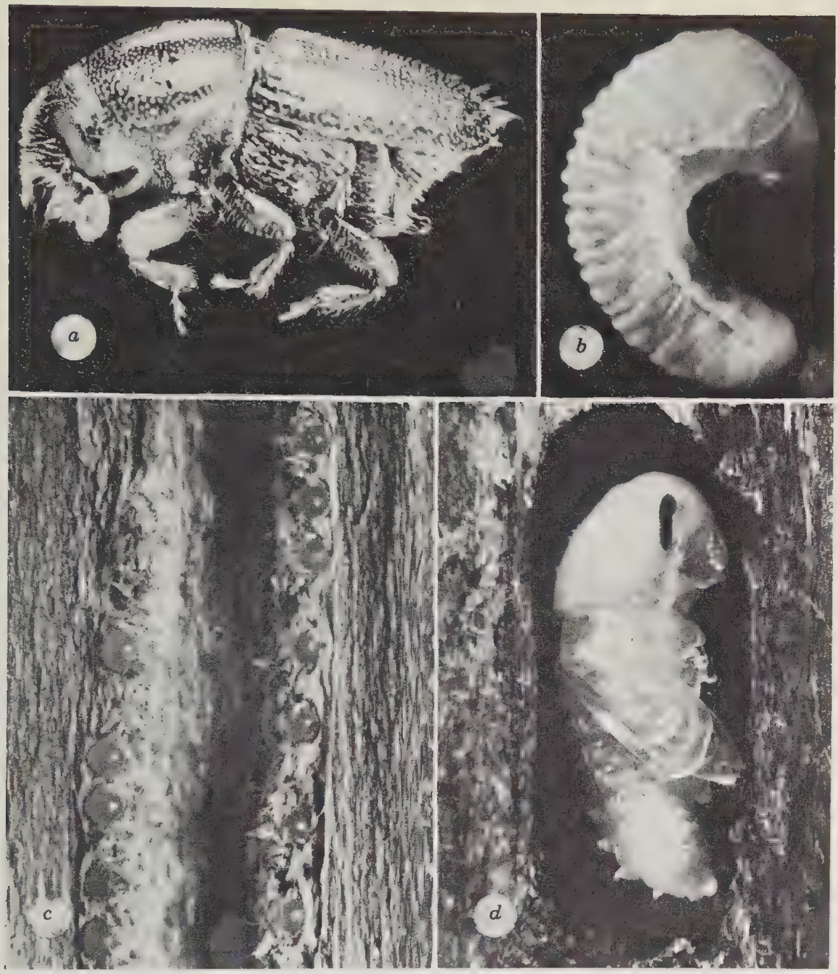


Fig. 361. The smaller European elm bark beetle; *a*, adult; *b*, larva; *c*, eggs; *d*, pupa; all greatly enlarged. (U.S.D.A.)

the wood and the inner bark. These galleries are parallel with the grain of the wood, and in niches along the sides are placed the globular, pearly white eggs (Fig. 361). From these eggs hatch the legless, white, brown-headed larvae which feed in the cambium region, constructing galleries across the grain of the branches. As the larvae increase in size the galleries are also widened, and, when fully developed, pupation occurs in the enlarged gallery tip (Fig. 362). In the latitude of New Jersey the length of the life cycle ranges from forty-five to sixty days under favorable condi-

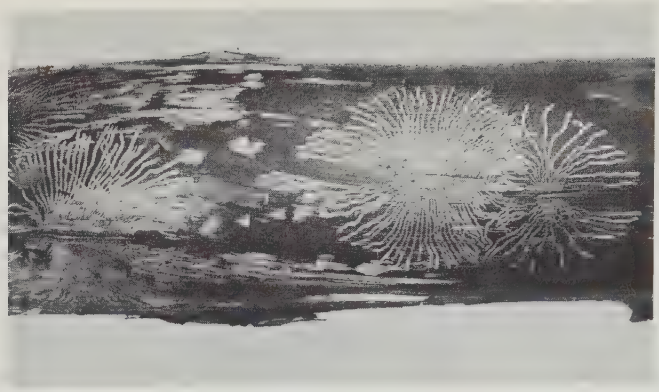


Fig. 362. Larval and adult galleries of the smaller European elm bark beetle. (U.S.D.A.)

tions, and two full generations and a partial third are produced each year. The overwintering larvae develop from the eggs laid late in the summer or early fall.

The native elm bark beetle presumably originated in the United States. It occurs in most of the eastern states from Maine to Virginia, in Missisippi, Kansas to Minnesota, and also in eastern Canada. It may be present throughout the natural range of the American elm, or approximately the eastern $\frac{2}{3}$ of the country. It feeds on various species of elm and is recorded as feeding on basswood.

The adult beetle is dull brown, a little less than $\frac{1}{8}$ inch long, and without the concave underside of the abdomen or prominent spine evident in *S. multistriatus*. The egg, larva, and pupa closely resemble the European elm bark beetle in color and appearance, and the life cycle is also very similar; the winter, however, is passed in both the larval and adult stages. Only diseased, dying, or recently cut elm trees are attacked, and the parent or egg galleries consist of two branches diverging from the point where the beetles enter the bark. These galleries extend across the grain, and the larval galleries almost always run with the grain.

Unless elm bark beetles are associated with Dutch elm disease, there is little need for control measures, since healthy elm trees are not subject to serious damage by the beetles. When elm leaves on a branch or two suddenly wilt, become yellow or dry, then drop off, the tree may have Dutch elm disease. Cut off several small branches showing these symptoms and examine for a brown discoloration in one or more of the annual growth rings. If present, the tree is probably infected with Dutch elm disease. To be positive a laboratory diagnosis is necessary.

Dutch elm disease can be checked by community-wide effort by killing

the bark beetles that carry the organisms. The most effective chemical is DDT applied as a spray just before the leaves appear and again about ninety days later. Emulsifiable concentrates are preferred. For dormant spraying with hydraulic equipment use a dilution containing 2% DDT, and for mist blowers 12% DDT. These concentrations are halved for application as foliar sprays. Methoxychlor and dieldrin are also effective chemicals for controlling these bark beetles.

Other helpful control measures are the removal and burning of all dead, dying, or diseased elm trees in a relatively large area where both the beetles and the disease are present, and proper pruning, fertilizing, and watering to keep remaining trees as vigorous as possible.

References: *Conn. Agr. Exp. Sta. Bul.* 420, 1939; *U.S.D.A. Agr. Inf. Bul.* 193, 1964; *Leaflet* 185, 1963; *J. Econ. Ent.*, 47:739–746, 1954.

SHOT-HOLE BORER

Scolytus rugulosus (Ratz.), Family Scolytidae

Introduced from Europe in 1878, this bark beetle has spread over most of the United States. Common hosts include peach, plum, cherry, apple, and pear. Its presence is indicated by the numerous small holes in the bark of twigs and branches (Fig. 363). These holes are about the diameter of small lead shot and are often filled with gummy exudates, especially on peach and other stone fruits. They are not serious enemies of healthy trees, but occasionally they may be found infesting broken, dead, or dying branches.

The adult beetle is $\frac{1}{10}$ inch or less in length, brown-black, with a short, stubby snout in which are the chewing mouthparts. The larva is a small, white, footless grub, slightly larger at its anterior end and about $\frac{1}{6}$ inch in length (Fig. 364).

Larvae of these beetles hibernate in their burrows beneath the bark,

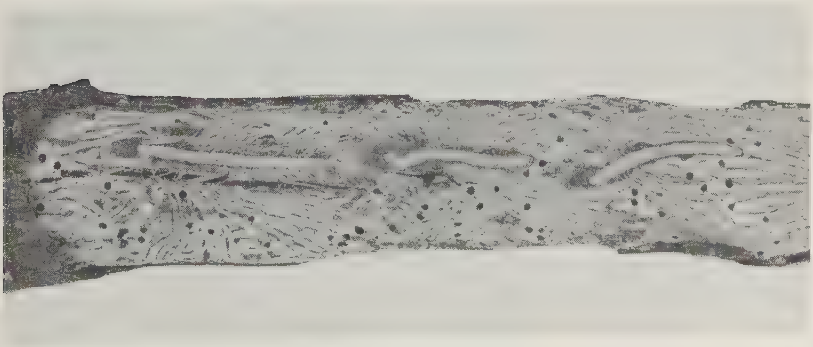


Fig. 363. Feeding damage by the shot-hole borer.

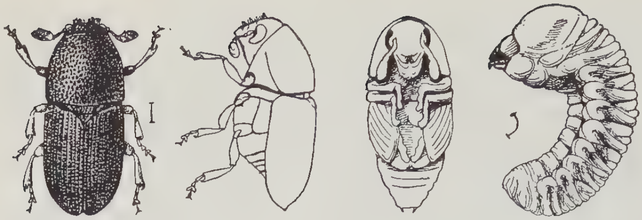


Fig. 364. The shot-hole borer, *Scolytus rugulosus* (Ratz.): *a, b,* adult; *c,* pupa; *d,* larva; enlarged. (U.S.D.A.)

complete their development, and emerge as adults in the spring or early summer. These adults bore into the twigs and branches, and make tunnels more or less parallel with the grain of the wood just under the bark where they deposit their eggs. The larvae extend their tunnels somewhat at right angles to the parent gallery, which may so injure the cambium layer that the branch is killed. When grown, the larvae pupate, transform to adults, and emerge from holes which they chew in the bark. These exit and entrance holes give the shot-hole effect. There are one or two generations per year in the North and three or more in the south.

The shot-hole borer is said to have several natural enemies, the most important being parasitic chalcid wasps.

Since healthy, vigorous, well-cared-for trees are less subject to attack by shot-hole borers, any operation that contributes to this end is of value in control. Removal and burning of infested or diseased branches or trees during the winter period destroy the insects while still in their burrows. This helps prevent the increase of beetles to the point where they might attack healthy wood. Orchards receiving a regular spray program are not troubled by this insect. Recommended insecticides are 2 pounds of 50% DDT wettable powder or 2 pounds of 15% parathion wettable powder to 100 gallons of water. To be effective, these sprays should be applied when the adults are emerging and before they lay eggs. This would be approximately early June and late August for the two-generation areas.

References: *U.S.D.A. Cir.* 270, 1950; *Agr. Handbook* 290, 1965.

FLATHEADED APPLE TREE BORER

Chrysobothris femorata (Olivier), Family Buprestidae

This flatheaded borer attacks practically all fruit, shade, or forest trees. It is widely distributed throughout the United States and sections of Canada, but on the Pacific Coast it is largely supplanted by a related species, *C. mali* Horn, the Pacific flatheaded borer. Both species cause

Fig. 365. (Left) the flatheaded borer, *Chrysobothris femorata* (Oliv.); (center) the Pacific flatheaded borer, *C. mali* Horn; and, (right) larva in burrow. (U.S.D.A.)

similar damage by tunnelling under the bark in the larval stage and feeding on the foliage as adults. Young trees are often attacked, as well as older trees that are unthrifty due to drought, defoliation, sun scald, or other factors.

The beetles are flat, bronzy-black, and nearly $\frac{1}{2}$ inch in length. The larvae are white, legless, about an inch long when fully grown, with the fore part of the body broad and flattened (Fig. 365). The adults are more prevalent in sunny locations.

Partly grown larvae hibernate in the burrows. In the spring before pupation, they tunnel a cavity almost at a right angle to the bark surface. Adults begin emerging in May and this continues until midsummer. Eggs are laid beneath scales of bark and on hatching the larvae burrow under the bark. Development is usually completed within one year, but sometimes two years are required.

Maintenance of tree vigor is considered of utmost importance. Shading the trunks of newly set trees by wrapping with paper or burlap impregnated with DDT inhibits egg deposition and kills newly hatched larvae. During the winter period, removal and destruction of wood containing the borers are of value in control. Spraying the tree trunks during the summer period with a residual-type insecticide to kill the tiny larvae before they burrow beneath the bark is effective. Recommended materials are DDT or dieldrin.

References: *U.S.D.A. Farmers' Bul.* 1065, 1919; *Tech. Bul.* 83, 1929; *Leaflet* 274, 1965; *Cir.* 270, 1950; *Ill. Nat. Hist. Cir.* 47, 1958.

ROUNDHEADED APPLE TREE BORER

Saperda candida Fabr., FAMILY CERAMBYCIDAE

This borer is a native American insect which attacks shadbush, wild crabs, mountain ash, and hawthorn, the importance being approximately in the order named. In addition, apple, pear, quince, plum, and cherry may also be injured, particularly when some of the preferred hosts are in the vicinity. Distribution is rather general throughout the area from Maine to North Dakota, south to Texas and central Georgia. Damage is caused by the larvae feeding in the cambium region near the ground level which results in girdling, and in the heartwood which weakens the trees so much that they are easily broken by winds. Young trees are especially vulnerable to attack if they are in the vicinity of shadbush or service berry.

The appearance of the insect is shown in Fig. 366. It is necessary to add that the adult ground color is light olive brown with conspicuous white stripes, and the larva is creamy white with darker mouthparts and head capsule.

The life cycle requires two to four years; three is the usual period. Pupation occurs in the spring of the last year of larval life and takes place in the galleries excavated by the larvae. Beetles are active from late April to September depending on the latitude. However, the greatest numbers

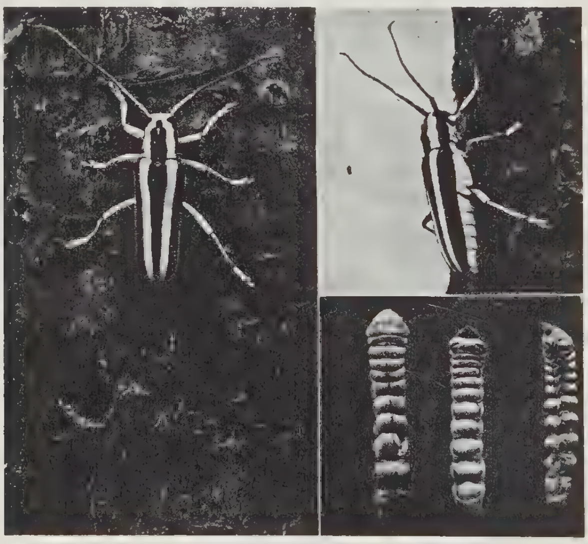


Fig. 366. The roundheaded apple tree borer, *Saperda candida* Fabr.; larvae, adults, and exit holes; natural size. (After Rumsey and Brooks.)

are to be found in June. Less than a week after the adults emerge egg-laying begins; the eggs are deposited in small cavities in the tree trunk, usually close to the ground. On hatching, the larvae bore into the tree and feed. In large trees the first year is spent in the sapwood, subsequent feeding being in the heartwood; in young trees they may go directly to the heartwood, and in such trees the work of a single larva may be enough to kill the tree. Much fibrous frass exuding from holes in the bark is an indication of larval activity.

Eradication of wild host plants from the vicinity of the orchard is advised. Removing the larvae by hand is feasible if only a few trees are involved. Good control of larvae in trees already infested has been obtained by injecting into the tunnels any of the following: a mixture consisting of 10 grams of PDB dissolved in 10 ml. carbon disulfide, dichloroethyl ether, or pyrethrum extract diluted 1 to 2 with ethyl alcohol. Best results from this method have been obtained by fall treatment, usually in September; spring treatment in June is also suggested. Bearing orchards receiving a regular spray program are not troubled by this insect, apparently because the adults are killed before they lay eggs. Young nonbearing orchards or shade trees that are subject to attack should be sprayed two or three times at ten- to fourteen-day intervals with 3 pounds of lead arsenate in 100 gallons of water. The first spray should be applied approximately three weeks after the calyx spray for apple. DDT and parathion are also effective in control; they are popular insecticides in many commercial orchard spray programs and no reports of borer infestations have been made where they have been applied.

References: *U.S.D.A. Dept. Bul.* 847, 1920; *Leaflet* 274, 1965; *N.Y. Agr. Exp. Sta. Bul.* 688, 1940; *Ohio Agr. Exp. Sta. Res. Bul.* 930, 1963.

PHLOEM NECROSIS LEAFHOPPER

***Scaphoideus luteolus*, V.D., Family Cicadellidae**

This white-banded leafhopper, a commom pest of elms, is important primarily because it is the known vector of the virus producing phloem necrosis of the American and winged elms. Once a tree is affected by this virus, death is certain though not immediate. The present known area of infection by this disease is from Ohio to Wyoming, south to Texas, east to South Carolina, and north to Lake Erie.

When elm leaves turn yellow, wilt, and drop off, the tree may be infected. Cut through the bark at several places around the lower trunk or on buttress roots and expose the inner bark. If the inner bark that lies next to the wood is a yellow or butterscotch color, sometimes flecked with brown, remove a strip of the discolored layer and place it in a stoppered

vial for a few minutes in a warm place. Phloem necrosis is present if the discolored tissue gives off a faint odor of wintergreen.

The leafhopper eggs are deposited in the outer bark of living elm trees and the winter is passed in this stage. Hatching occurs in the spring soon after elm foliage appears. The nymphs pass through five instars, and approximately fifty or more days later the adult stage is reached. The adults are brown with faint mottling, and nearly $\frac{1}{4}$ inch in length. They are present throughout the remainder of the summer, during which they deposit the overwintering eggs.

To prevent the spread of the disease it is necessary to control the leafhoppers. Spraying thoroughly with methoxychlor or DDT has been most effective if applied when the elm leaves are fully grown, usually in June, followed by a second application in mid-August. For hydraulic sprayers use an emulsion containing 1% and for mist blowers 6% insecticide. Since DDT and methoxychlor favor the development of spider mites it is well to include a compatible miticide in the sprays.

References: *J. Econ. Ent.*, 42:729–732, 1949; *U.S.D.A. Leaflet* 329, 1952.

ROSE SLUGS

Order Hymenoptera, Family Tenthredinidae

The larvae of three species of sawflies injure roses by skeletonizing the foliage or chewing large ragged holes in the leaves. These larvae (Fig. 367) are referred to as "slugs" because of their resemblance to those animals, and false caterpillars because of their resemblance to the larvae of moths and butterflies. The adults are black-bodied, four-winged insects about the size of the house fly. They insert their eggs into the leaf tissue.

The bristly rose slug, *Cladius isomerus* Norton, is yellow-green with a darker green line down the back, and has 7 pairs of abdominal prolegs. The body is covered with stiff hairs from which it derives its common name. When fully grown it is about $\frac{1}{2}$ inch in length. It skeletonizes the leaves when young but may devour the entire leaf in later instars. Pupation takes place inside a thin membranous cocoon attached to objects above or on the ground. There are six overlapping generations a year in the vicinity of Washington, D. C.

The rose slug, *Endelomyia aethiops* (F.), formerly called the European rose slug, skeletonizes the leaves usually from the upper surface. The pale green larva is nearly $\frac{1}{2}$ inch long when fully grown, with eight pairs of abdominal prolegs. This species has only one generation per year. It appears in early spring, completing its development and entering the soil where it remains inactive inside an earthen cell until the following spring.

Fig. 367. Rose slugs: (top) bristly rose slug, *Cladius isomerus* Norton; (middle) rose slug, *Endelomyia aethiops* (F.); (bottom) the curled rose sawfly, *Allantus cinctus* (L.). (U.S.D.A.)

The curled rose sawfly, *Allantus cinctus* (L.), sometimes referred to as the coiled rose worm, eats the entire leaf tissue, usually from a curled position along the leaf edges. The larva has eight pairs of abdominal prolegs. It is green with the sides and legs grayish, and can be distinguished from the other species by its yellow-brown head marked with a black spot. Pupation occurs inside cells bored in the pith of soft wood or pruned rose stems. There are two generations each season and the winter is passed in the pupal stage.

Dusts containing either 3% DDT, 5% malathion, or 0.75% rotenone easily control these insects. The all-purpose rose dusts are also quite satisfactory if they contain at least one of these insecticides.

References: *U.S.D.A. Misc. Pub.* 626, 1948; *Agr. Inf. Bul.* 237, 1962.

MIMOSA WEBWORM

Homadaula albizziae Clarke, Family Glyphipterygidae

This web-forming defoliator that attacks mimosa and honey locust may be found in almost all areas of the eastern half of the United States where these hosts abound. At times damage is severe and the trees greatly disfigured. The species was discovered in the vicinity of Washington, D. C. in 1940 and is thought to be native to the Indo-Australian region.

Adults of mimosa webworm have a wingspread of about $\frac{1}{2}$ inch. The forewings are silvery gray with about twenty conspicuous black dots; the hindwings are brownish gray. In Ohio, moths have been observed from mid-May to mid-October.

The pearly gray oval eggs are deposited on the flowers and leaves of the hosts. The color soon changes to a shade of pink, and hatching occurs within a few days. Larvae spin webs and pull leaflets together into tunnel-like masses where they feed on the inner surfaces. Damaged leaves turn brown and often absciss. When disturbed, larvae will twist violently. Mature larvae are nearly $\frac{1}{2}$ inch long, vary from pale green to dark brown, and have five longitudinal white stripes. Fully grown larvae often descend to the ground on silken threads where they pupate within silken cocoons in the litter, bark crevices, or other objects; others pupate in webbed foliage. Winter is passed in the pupal stage and four generations per year have been observed in Ohio.

Three to five foliar sprays of carbaryl, DDT, lead arsenate, dieldrin, toxaphene, or trithion provide excellent protection from this pest. One treatment with the systemic organophosphorus compounds bidrin, phorate, or Di-Syston has prevented damage for the entire growing season. These highly toxic compounds must be used with extreme care.

References: *Proc. U. S. Nat. Mus.*, 93:205–208, 1943; *J. Econ. Ent.*, 40:546–553, 1947; *Arborist's News*, 29:17–20, 1964; *Ohio Res. Bul.* 983, 1966.

CONIFER SAWFLIES

Order Hymenoptera, Family Diprionidae

Colonies of caterpillars devouring the needles of pine trees and other conifers are usually the larvae of sawflies. Sometimes they become so numerous that complete defoliation of the tree results. Repeated yearly attacks will result in death of the tree. The caterpillars are 1 inch or less in length with six to eight pairs of abdominal prolegs without crochets. Adults are typical sawflies with four membranous wings and a broad attachment of abdomen to thorax. There are several injurious species in North America.

The European pine sawfly, *Neodiprion sertifer* (Geoffroy), overwinters as eggs in slits in the needles. These hatch the following April or May and the larvae feed on the old needles, becoming fully grown by late May or early June. The black-headed larvae are gray-green with a longitudinal dorsal line of lighter shade; laterally there are two white lines bordering a stripe of intense green to black. Pupation occurs in a brown cocoon, mainly in the duff beneath the trees, but occasionally some cocoons are found on twigs. Adults emerge in autumn and lay their eggs. Only one generation develops each year. The favored hosts are red, Scotch, jack, Japanese red, Swiss mountain, and mugho pines.

The red-headed pine sawfly, *N. lecontei* (Fitch), frequently attacks young plantings of a wide variety of hard pines and other conifers. Young larvae are white and unspotted with a brown head; later, after a series of molts, they become yellow with six rows of black dots on the body, and the head becomes red. Winter is passed as brown cocoons in the duff under the trees. One or two generations develop each year.

The white-pine sawfly, *N. pinetum* (Norton), is mainly a white pine pest but it occasionally attacks other species. It resembles the red-headed species but has only four rows of black dots on the body, and the head is black. The life cycle is also similar to that of the red-headed pine sawfly.

Other sawfly species of importance at times are the red-pine sawfly, *N. nanulus* Schedl; the Swaine jack-pine sawfly, *N. swainei* Middleton; the jack-pine sawfly, *N. pratti banksianae* Rohwer; the balsam-fir sawfly, *N. abietis* (Harris); the lodgepole sawfly, *N. burkei* Middleton; and the hemlock sawfly, *N. tsugae* Middleton.

Natural enemies include rodents, predaceous beetles, a few insect parasites, and virus diseases.

If chemical control measures become necessary apply lead arsenate, DDT, or methoxychlor when larvae appear.

References: *J. Econ. Ent.*, 32:887–888, 1939; *U.S.D.A. Misc. Pub.* 657, 1950; *Tech. Bul.* 1118, 1955; *Ill. Nat. Hist. Survey Cir.* 47, 1958; *Ohio Res. Bul.* 983, 1966.

BOXELDER BUG

Leptocoris trivittatus (Say), Family Corizidae

The boxelder bug is widely distributed and occurs almost everywhere boxelder trees grow. It feeds primarily on the pistillate or seed-bearing trees by sucking the sap from the leaves, tender twigs, and developing seeds. Occasionally it has been observed feeding on maple and ash. The plant damage is not considered important and the bug is much better known as a source of annoyance to home owners because of its habit of congregating in large numbers in or on the outside of the houses in autumn, when the adults are seeking hibernation quarters. If they gain entrance to houses no harm results to clothing, foods, or other household articles.

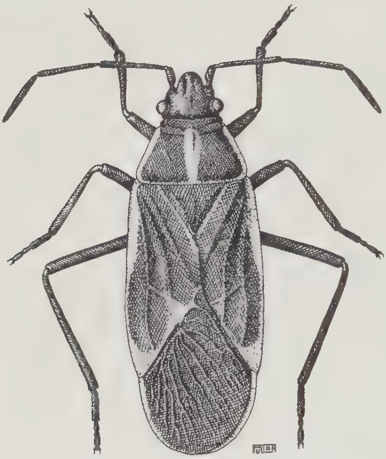


Fig. 368. The boxholder bug. (Courtesy of Knowlton, Utah Agr. Exp. Sta.)

The adult bug (Fig. 368) is about $\frac{1}{2}$ inch long, brownish-black, with three longitudinal red stripes on the thorax and red margins on the basal half of the wings. Under the wings the abdomen is bright red.

Overwintering adults leave their hibernating quarters with the coming of warm spring weather and begin laying red eggs in crevices of the bark and on other objects in the vicinity of the host plant. Hatching occurs in about fourteen days and new adults appear in July and begin laying eggs that result in a second generation by early autumn.

Spraying the infested plants in June while nymphs are present will reduce the bug population on trees in the vicinity of homes. Aldrin, chlordane, diazinon, dieldrin, dylox, malathion, lindane, and carbaryl have been employed with success. The dosage required to kill the adult bugs is usually

much higher. Follow the directions on the insecticide label. Practical control of these insects inside the home consists of collecting them with a tank-type vacuum cleaner and destroying them. Applying aerosols containing DDD plus synergized pyrethrins to the bugs has given good control. Silvicultural control consists of having nurserymen propagate boxelder trees only from staminate cuttings. To eliminate completely the bug problem all pistillate boxelder trees should be removed from a given residential area and replaced with tree species that have less insect pests and are of higher ornamental value.

References: *U.S.D.A. Misc. Pub.*, 657:118–119, 1950; *Wis. State Dept. Agr. Bul.*, 330:22, 1955; *Proc. Ent. Soc. Ontario*, 92:202–203, 1961; *Rutgers Univ. Ext. Leaflet* 371, 1963.

17

Insects Injurious to Pome Fruits

EUROPEAN RED MITE

Panonychus ulmi (Koch), Family Tetranychidae

Introduced from Europe some time previous to 1911, this spider mite has become one of the most important pests of fruit trees in northern United States and adjacent regions of Canada. It has not been reported on deciduous trees south of 34° N. latitude. The mite attacks elm, apple, pear, peach, plum, and prune to an injurious extent, and may be found on other deciduous trees and shrubs as well.

Sap removal by the piercing-sucking active stages results in bronzing and off-colored foliage and, under severe infestations, defoliation, and undersized, poorly colored fruits.

The mites are usually rusty in color, but newly emerged females are bright velvety red, changing in time to dark red-brown. Males are dull green to fulvous. Prominent, curved, dorsal white spines on the body help distinguish the red mite from red individuals of the two-spotted spider mite. The red-orange eggs of the European red mite are easily recognized by the prominent hair-like projection on the upper side.

Winter is passed in the egg stage, usually on twigs and branches of the hosts. Hatching takes place at or before the pink stage. The first instar has six legs, and, after molting, succeeding instars (called protonymphs, deutonymphs, and adults) all have eight legs. Females are globular-shaped; the males are narrower with a more pointed abdomen (Fig. 369). Development from egg to adult is affected by temperature but generally requires one to three weeks. Fertilized eggs develop into males and females, but unfertilized eggs develop only into males. There may be as many as six to eight overlapping generations each season. Summer eggs are laid on the foliage and winter eggs are laid on the twigs. Production of winter eggs is influenced by photoperiod, temperature, and nutritional factors in the leaves. Deposi-

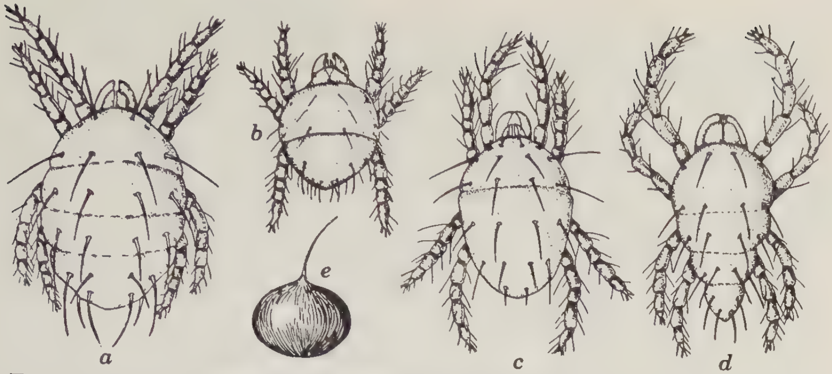


Fig. 369. The European red mite, *Panonychus ulmi* (Koch): *a,* adult female; *b,* first instar; *c,* deutonymph; *d,* adult male; *e,* egg. (Newcomer & Yothers, U.S.D.A.)

tion of winter eggs usually begins in mid-August and continues until cold weather.

Several predators attack this mite as well as other orchard mites. A lady beetle, *Stethorus picipes* Casey, is an important predator in the Northwest. Others of importance are the mites in the genus *Typhlodromus,* the anthocorid bug, *Orius insidiosus* (Say), and the predatory thrips *Scolothrips sexmaculatus* Pergande and *Haplothrips faurei* Hood. Frequently this group of predators is so important in keeping plant-feeding mite populations checked that no miticides are necessary. DDT and related chlorinated insecticides favor the development of phytophagous spider mite populations because these compounds are toxic only to the predators that normally keep the spider mites checked.

For killing the eggs, a dormant or delayed dormant application of a 3% superior- or regular-type oil emulsion is still a recommended practice since it may prevent the rapid development of resistant strains. After the eggs hatch, any one of the following materials may be added to the spray mixture: chlorbenside, Genite, tetradifon, chlorobenzilate, guthion, demeton, Kelthane, ovex, EPN, Sulphenone, Aramite, malathion, parathion, trithion, ethion, phosphamidon, fenson, Morestan, or TEPP. Some of these chemicals are applied in combination with oil emulsions. When four to six mites are found per leaf during the months of June, July, and August, applications of miticides are justified. Two applications at an interval of seven to ten days are recommended for most chemicals.

Continuous use of the same miticide favors the development of resistant strains of mites. To avoid or delay this development growers are urged to rotate the use of different classes of miticides. For example, apply oil in early season each year and in mid-summer the first year use an organo-

phosphate, the second year a chlorinated hydrocarbon, the third year a sulfur-base compound, and the fourth year begin this sequence of sprays again.

Selection of the proper chemical depends on such factors as cost, availability, toxicity to other pests and beneficial insects, presence of resistance, phytotoxicity, and hazards in handling. Your extension entomologist will help solve these problems.

References: *U.S.D.A. Tech. Bul.* 89, 1929; *Va. Agr. Exp. Sta. Tech. Bul.* 98, 1946; *J. Econ. Ent.*, 46:112–115, 894–896, 1085–1086, 1953; 57:35–37, 1964; *Hilgardia*, 21:253–287, 1952; *Ohio Agr. Exp. Sta. Cir.* 37, 1956.

OTHER SPIDER MITES

Order Acarina, Family Tetranychidae

In addition to the European red mite and the two-spotted spider mite (p. 308), there are many other species that attack a wide variety of trees, shrubs, flowers, and agricultural crops. A few of the more common ones are mentioned here with some comment on their habits, appearance, life cycle, distribution, and control. They all cause injury by removal of plant sap with their piercing-sucking mouthparts.

Fig. 370. Dorsal and ventral (legs removed) views of the clover mite, *Bryobia praetiosa* Koch (U.S.D.A.)

Clover Mite, *Bryobia praetiosa* Koch, is a world-wide pest of fruit trees, clover, and other legumes, as well as a number of garden and field crops, including cotton. It may also become a nuisance by invading houses, particularly in the spring and occasionally in autumn. It is seldom found on the aerial portions of trees, does not web leaves with silk, and is more tolerant of cold than the brown mite. Winter is passed principally as smooth, spherical, cherry red eggs and as flattened, dark brown to dull green adults with rather long front legs (Fig. 370). The winter eggs hatch in early spring into scarlet nymphs which, on reaching the adult stage, lay the summer eggs that usually estivate until September. Occasionally some of these eggs hatch, giving rise to a succession of summer generations. Only one generation in the fall develops from the hatching estivating eggs. Control is accomplished with the same miticides as recommended for the European red mite. Keeping all turf plant growth 18 inches from the foundation of homes prevents these mites from entering.

Brown Mite, *Bryobia arborea* (Morgan and Anderson), is of economic importance in many countries, living in the aerial portions of orchard trees, for example, apple, almond, apricot, cherry, peach, pear, and plum. It closely resembles the clover mite with which it has been confused. Winter is passed as spherical red eggs on twigs and branches; these begin hatching in the late delayed dormant to early pink periods of apple tree development and this continues until full bloom is reached. No webbing of silk is associated with their foliage feeding. The maximum number of generations of this mite in Canada was four. With the approach of autumn migration from the leaves back to the twigs and branches takes place where the overwintering eggs are deposited.

Pacific Spider Mite, *Tetranychus pacificus* McGregor, is one of the most serious pests of deciduous fruits in western United States. It also attacks many small fruit, legume, and vegetable crops, as well as ornamental plants and weeds. Adult females are pale green with dorsal dark spots medially and a pair of dark spots near the posterior end of the body. Overwintering females are often bright orange and are found under the bark of trees or in the duff on the ground. Feeding is general over the undersurface of the leaves, and dense webbing is produced. The eggs are spherical and pearly white.

Schoene Spider Mite, *Tetranychus schoenei* McGregor, is widely distributed throughout the southeastern states, attacking deciduous fruit and ornamental trees and shrubs, as well as field crops. Adult females are pale green with four dorsal darkened spots. Overwintering females are bright orange. The development, webbing, and feeding habits are similar to those of the Pacific mite.

Four-Spotted Spider Mite, *Tetranychus canadensis* (McGregor) (Fig. 371), has been found in many areas of the eastern half of the United States and in southern Canada. Specimens have been taken from apple, cotton, rose, elm, linden, plum, horse chestnut, and osage orange. Adult females resemble those of the Schoene mite. The biology of this species is the same as for *T. schoenei.*

Atlantic Spider Mite, *Tetranychus atlanticus* McGregor, is found throughout the United States. It commonly feeds on cotton, strawberries, legumes, ornamental shrubs, and fruit trees. The appearance and life cycle are similar to the two-spotted mite. It is also called the strawberry spider mite.

Other species are the McDaniel spider mite, *T. mcdanieli* McGregor and the Willamette spider mite, *Eotetranychus willamettei* (McGregor), found in California, Oregon, Utah, Washington, and British Columbia, on grapes and apple trees; and the Garman spider mite, *E. uncatus* Garman, found in Massachusetts and Connecticut on apple. These species resemble many

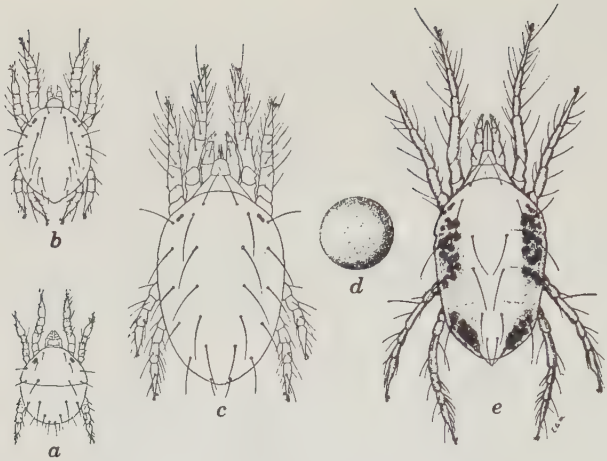


Fig. 371. The four-spotted spider mite, *Tetranychus canadensis* (McGregor): *a,* first instar; *b,* second instar or protonymph; *c,* third instar or deutonymph; *d,* egg; *e,* adult female. (U.S.D.A.)

of the mites already described in greater detail. Often a trained acarologist may have to make the final determination of species. References cited should be of value to those interested in further details concerning spider mites. Control measures are the same as for the European red mite.

References: *Conn. Agr. Exp. Sta. Cir.* 180, 1951; *Bul.* 552, 1952; *Hilgardia,* 21 (9), 1952; 22 (7), 1953; *Va. Agr. Exp. Sta. Tech. Bul.* 87, 1943; 124, 1956; *J. Econ. Ent.,* 50:135–141, 1957; *Can. Ent.,* 90:23–42, 1958.

APPLE APHIDS

Order Homoptera, Family Aphididae

Three species of aphids are usually found on apple and related hosts every year, sometimes in destructive numbers. They are known as the apple aphid, *Aphis pomi* DeGeer (Fig. 372), the rosy apple aphid, *Dysaphis plantaginea* (Passerini) (Fig. 373), and the apple grain aphid, *Rhopalosiphum fitchii* (Sanderson) (p. 198). All species are widely distributed in the apple-growing areas of North America. Both foliage and fruits are injured by the piercing-sucking nymphs and adults. Evidence of their activity is indicated by curled, twisted, stunted leaves, especially the tender terminal growth of new shoots, and stunted malformed clusters of fruits later in the season (Fig. 374). Rosy aphids are considered the most destructive species, with *A. pomi* sometimes becoming a problem in some areas.

All three species have very similar life cycles. Winter is passed in the egg stage on twigs, usually around buds or in crevices in the bark (Fig.

Fig. 372. The apple aphid, *Aphis pomi* DeGeer; ovoviviparous female, young nymph, oviparous female, and spring migrant.

Fig. 373. The rosy apple aphid, *Dysaphis plantaginea* (Passerini): *a*, ovoviviparous female; *b*, fall migrant; *c*, oviparous female, and *d*, spring wingless form. (U.S.D.A.)

375). These begin hatching in the spring just as the buds are in the green tip stage. Newly hatched nymphs are all wingless females and when fully grown are called stem mothers. These parthenogenetic females give birth to young, with repeated generations occurring about every two weeks. Early in the summer winged forms are produced which migrate to new host plants of the same species or to plants of a different species. These alternate hosts are often called the secondary hosts. Rosy aphids may remain on apple throughout the summer, but they usually migrate to narrow leaf plantain; apple grain aphids remain on apple a shorter period and migrate

Fig. 374. Fruit clusters damaged by apple aphids.

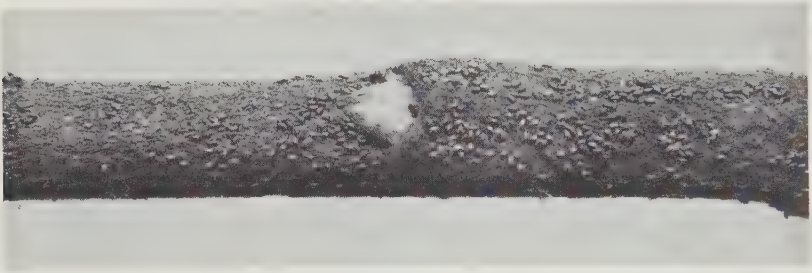


Fig. 375. Eggs of apple aphids. (Courtesy of Cutright, Ohio Agr. Exp. Sta.)

to grains and grasses, usually before they have done any damage to apple; *Aphis pomi* is usually a permanent resident of apple and related trees.

Reproduction continues throughout the summer, and in autumn winged forms develop on the secondary hosts that return to the primary host. Here are born nymphs that develop into true sexual forms; these mate, the females depositing the overwintering eggs. The eggs are green when first laid but soon turn shiny black.

Color and cornicles serve as useful characters to distinguish newly hatched nymphs. Rosy aphids are very dark purple, covered lightly with gray powder, and the cornicle length greatly exceeds the diameter; apple grain aphids are dark green, and the cornicles scarcely project from the abdomen; the apple aphid is green, with the cornicle length about equal to the diameter. Stem mothers of the rosy aphid are slate-colored, some rosy or pink, all with dark appendages; those of apple grain aphids are light green, having a median dorsal dark stripe with cross-bars of the same color and pale yellow appendages with darkened tips; those of apple

aphids are yellow-green with black cornicles and darkened tips on the antennae, tarsi, and tibiae.

Besides climatic factors which play an important role in natural control, there are many natural enemies of aphids, such as lady beetles, syrphid fly larvae, and aphid lion predators, and the parasite, *Aphidius testaceipes* (Cresson). Frequently there is no need for chemical control because of these natural control agents.

Recommended ovicides are dormant applications of 3% oil emulsion alone or in combination with the sodium salt of 4,6-dinitro-o-cresol (DNOC), or 4,6-dinitro-o-cyclohexylphenol (DN-Dry Mix No. 1). The triethanolamine salt of 4,6-dinitro-o-secbutylphenol (known as DN-289 or Elgetol 318) is also effective as a dormant spray. This chemical must not be applied in combination with dormant oil. After the eggs hatch any of the following insecticides may be used in the spray program if the infestation seems serious enough to justify their cost: BHC, lindane, demeton, diazinon, endosulfan, guthion, malathion, parathion, phosphamidon, or TEPP. BHC and lindane are for use only in pre-blossom sprays. Parathion and demeton are phytotoxic to McIntosh and Cortland varieties.

References: *Ohio Agr. Exp. Sta. Bul.* 464, 1930; *Conn. Agr. Exp. Sta. Bul.* 552, 1952; *Calif. Agr. Exp. Sta. Leaflet* 76, 1966; *U.S.D.A. Agr. Handbook* 290, 1965.

WOOLLY APPLE APHID

Erisoma lanigerum **(Hausmann), Family Aphididae**

This woolly aphid occurs in practically all the apple-growing districts of the world. Besides apple, it attacks elm, mountain ash, and species of hawthorn. It feeds on plant sap from the roots as well as from the upper parts of the trees. Above ground it is found chiefly on the trunks, limbs, and twigs, in old pruning scars or wherever the bark is tender. This injury is not considered as serious as that produced by the root-feeding forms, which cause gall-like swellings (Fig. 376). On young seedlings root injury may be quite severe. The insects are recognized by the white woolly covering, which is predominantly at the posterior end of their blue-black bodies (Fig. 377).

The life history of this aphid is rather complicated. Eggs are laid, usually on the bark of elm trees in the fall; these eggs hatch in the spring, and the wingless, parthenogenetic, ovoviviparous stem mothers establish colonies on the terminal leaves, which soon become curled and stunted from the feeding. By early summer a generation of winged forms appears; they fly to apple and other hosts and there they establish new colonies. Repeated generations are produced, and some of the individuals crawl to the tree roots where they may continue to reproduce indefinitely. In the fall, winged individuals again develop; they fly back to elm where they give birth to the

Fig. 376. Woolly apple aphids on stem of seedling tree and swellings made on roots, slightly enlarged. (Rumsey and Brooks.)

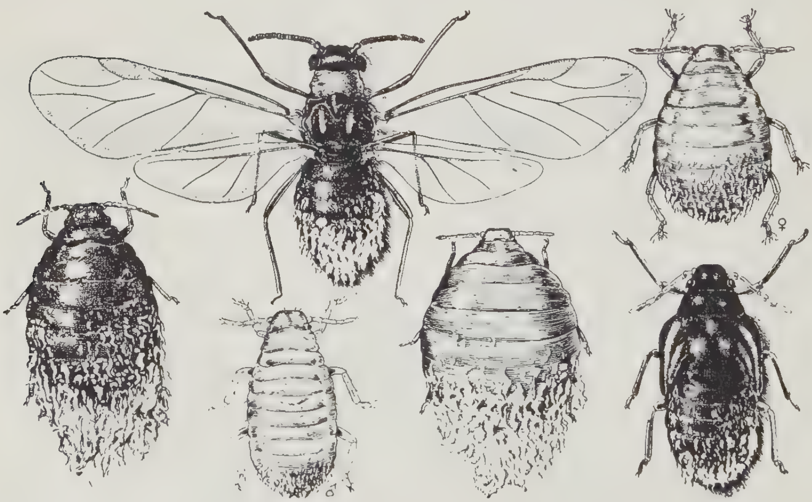


Fig. 377. Various stages of the woolly apple aphid, *Eriosoma lanigerum* (Hausmann). (Baker, U.S.D.A.)

Fig. 378. *Aphelinus mali* (Hald.), a very effective parasite of the woolly aphid; (left) pupa; (right) larva. (U.S.D.A.)

sexual forms, which eventually mate and lay the overwintering eggs. Not all the aphids return to elm, some wingless forms remain on apple all winter, both above and below ground, thus maintaining a continuous infestation on this host.

The woolly pear aphid, *Erisoma pyricola* Baker and Davidson, is a related species similar in appearance and life cycle. Its alternate host is elm, and the control measures are the same as for woolly apple aphid.

Some variation exists in susceptibility of apple varieties to attack by woolly aphids, Northern Spy being somewhat resistant. Syrphid fly larvae and lady beetles are considered important predators. A chalcid wasp, *Aphelinus mali* (Hald.) (Fig. 378), is an important parasite which has kept woolly aphids checked in all areas where it has been introduced. However, with the advent of DDT for codling moth control, populations of this wasp have been reduced so much in some regions that woolly aphids are again a problem.

If aphids become abundant the following chemicals will control them: BHC, lindane, Baygon, demeton, diazinon, dimethoate, endosulfan, guthion, malathion, and parathion. BHC and lindane are recommended only for young or nonbearing trees, or on bearing trees no later in the season than the calyx spray.

References: *Va. Agr. Exp. Sta. Tech. Bul.* 57, 1935; *Maine Agr. Exp. Sta. Bul.* 256, 1916; *J. Econ. Ent.*, 43:463–465, 1950; 57:1009, 1964; *U.S.D.A. Agr. Handbook* 290, 1965.

CODLING MOTH

Carpocapsa pomonella (L.), Family Olethreutidae

The codling moth, long known as an apple pest, was introduced into this country from Europe by early settlers. It now occurs wherever apples

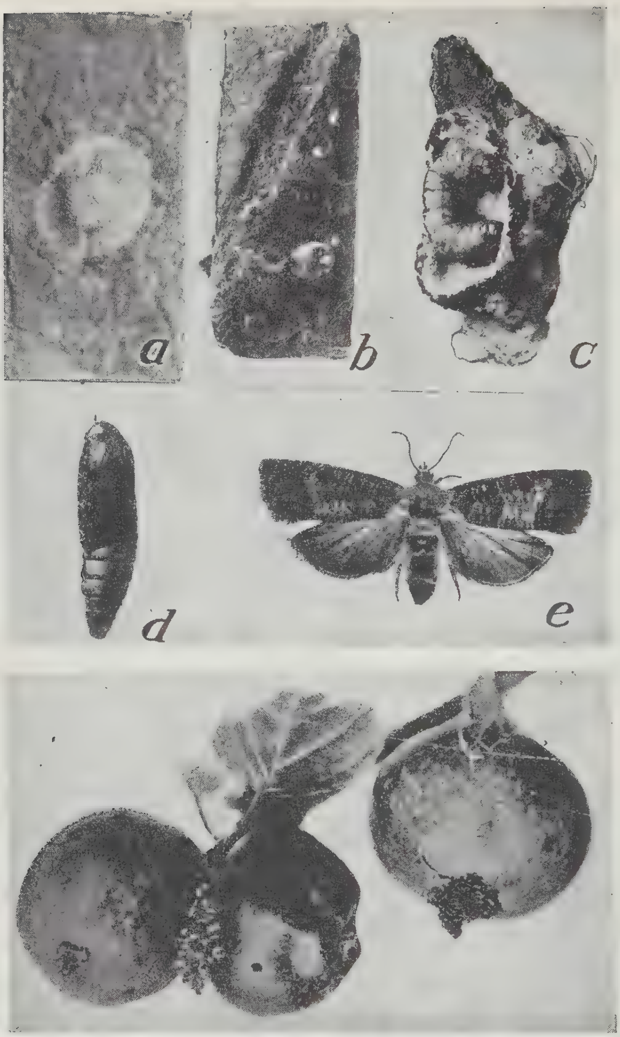


Fig. 379. The codling moth, *Carpocapsa pomonella* (L.): *a,* egg; *b,* larva just emerging from the egg; *c,* larva in cocoon; *d,* pupa; and *e,* adult. (Below) infested apples.

are grown and is generally considered one of the most important pests of the crop. Pear, quince, English walnut, and occasionally other fruits are also attacked. Injury is caused by the larval stage, which tunnels into the fruits, usually to the core, lowering their commercial value and keeping quality. Blemished marks called "stings" also result when larvae chew into fruits

that have been treated with slow-acting poison sprays, such as lead arsenate.

The moth has a wing expanse of nearly $\frac{3}{4}$ inch; the fore wings are gray-brown, crossed with lines of lighter gray and with deep golden or bronzed areas near the tips. The larva is white, often tinged with pink; it has a brown head, and is $\frac{1}{2}$ an inch in length when fully developed (Fig. 379).

Only fully grown larvae survive the winter, hibernating in silken cocoons in places of concealment on or near apple trees, or in and about packing sheds. Pupation takes place in the spring. Moths begin emerging about the time that apples are in bloom, live for two or three weeks, and deposit some thirty to forty eggs per female. Most moths of the first brood are present late in May and early in June. They lay many of their eggs between sundown and 10 P.M.; few eggs are laid, however, if the temperature is below 60° F. The tiny, white, flattened eggs with crinkled edges are approximately the size of a common pinhead (Fig. 380). They are placed on leaves, twigs, and fruits. Usually the weather is cool when the first eggs are laid, and about two weeks are required for incubation. In hot weather the eggs hatch in five days. The young larvae bore into the fruits, often entering through the calyx (Fig. 381), feed for nearly three weeks, then leave and spin cocoons in the places in which they normally hibernate. Approximately two weeks later the moths of the next generation begin to emerge, and the cycle is repeated. Sometimes the second-brood moths appear before those of the first-brood cease their activity, resulting in overlapping of generations. In more northern areas some first-brood larvae do not pupate but remain in their cocoons until the following spring. Three nearly complete

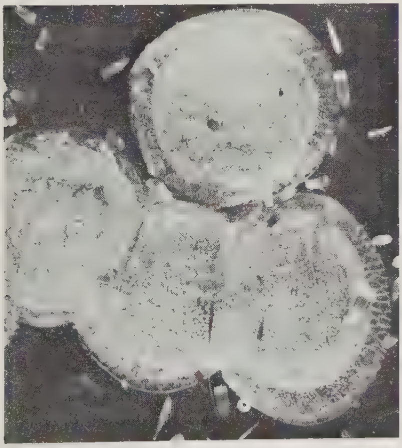


Fig. 380. Codling moth eggs, greatly magnified. (Ohio Agr. Exp. Sta.)

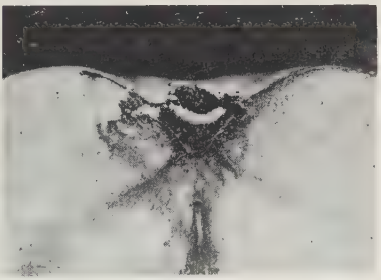


Fig. 381. Codling moth larva feeding in the calyx of an apple.

Fig. 382. *Ascogaster quadridentata* Wesm., a parasite of the codling moth. (Cox, N. Y. Agr. Exp. Sta.)

generations and a partial fourth are known to occur in the southernmost apple-growing areas.

Tremendous variation in codling moth populations in different orchards and orchard regions, and in the same orchard or region at different periods, indicate that the insect is much affected by natural controlling agencies. Climatic factors, especially temperature, are known to play a great part in determining abundance. Biological factors are also of some value, with the larval parasite, *Ascogaster quadridentata* Wesm. (Fig. 382), and the egg parasite, *Trichogramma minutum* Riley, probably the most important.

Because of the necessity for controlling both insects and diseases on fruits most states have developed spray programs for their growers. These embody the best combination of compatible materials to bring about effective control for a particular region.

Although details of a spray program for codling moth control do vary widely, the main features can be given. The first spray is called the petal-fall; it is applied when nearly all petals have fallen and before the calyx closes. It is followed by a variable number of cover sprays, usually four to six at approximately two- to three-week intervals. Proper timing of sprays is essential, and this may be determined locally by observations on moth activity by means of bait pails. The total number of cover sprays depends on many factors. These are intensity of the infestation, seasonal variations, possibility of excess poisonous residues, and probable returns for the extra materials and effort expended. Regardless of the total cover sprays employed, it is important that a second-brood spray (sometimes designated as the fifth cover spray) be applied about ten weeks after petal-fall, which would normally be in late July or early August for most fruit-growing areas.

Lead arsenate has been the standard control chemical for a number of years and is still recommended where its performance has been satisfactory, although DDT is now the outstanding codling moth insecticide. The main objection to DDT is that it favors the development of plant-feeding mites by killing the predaceous mites that normally hold them in check. Since lead arsenate has little effect on predaceous mites its use in early sprays for codling moth delays the development of a mite problem and helps to eliminate some of the later required miticide sprays. To check the development of plant-feeding mites and to kill both plum curculio and codling moth, organophosphorus compounds are recommended, especially for commercial growers. These compounds are parathion, guthion, malathion, and diazinon. In some regions combinations of the organophosphorus compounds with DDT, methoxychlor, or carbaryl are recommended. Each state or province prepares its yearly apple spray program. Obtain the latest control recommendations from your extension entomologist. Besides an effective insecticide, thorough coverage and proper timing are essential to successful fruit insect control.

References: *Ohio Agr. Exp. Sta. Bul.* 583, 1937; *Res. Bul.* 930, 1963; *Conn. Agr. Exp. Sta. Bul.* 552, 1952; *U.S.D.A. Cir.* 270, 1950; *Calif. Agr. Exp. Sta. Leaflet* 76, 1966; *Wash. Agr. Exp. Sta. Bul.* 340, 1936.

APPLE MAGGOT

Rhagoletis pomonella (Walsh), Family Tephritidae

The apple maggot is a native insect widely distributed from North Dakota to Oklahoma eastward. It has been seriously injurious primarily in the northeastern states and Canada. Hawthorn, plum, pear, and cherries also serve as hosts. Crab apples are invariably infested by this pest. A related species, *R. mendax* Curran, is called the blueberry maggot, important as a pest of the blueberry crop. Of the orchard fruits, apples are the most seriously damaged.

The adult is a fly, a little more than $\frac{1}{4}$ inch in length, dark brown, with light bands on the abdomen and both light and dark markings on the wings. Larvae are white tapered maggots slightly smaller than those of the house fly (Fig. 383).

Winter is passed as puparia in the soil. Adult flies begin emerging during the latter part of June, continuing for a month or more. However, some overwintering puparia remain inactive, the adults not appearing until the second summer. A week or more elapses after adult emergence before eggs are deposited. The tiny white eggs are inserted underneath the skin of the apple, the susceptible varieties being Cortland, Wealthy, Delicious, and others that mature early and have sweet or subacid characteristics. Hatching occurs within a few days and the larvae mine in the flesh leaving irregular

Fig. 383. The apple maggot, *Rhagoletis pomonella* (Walsh): adult, larva, and eggs. (Porter, U.S.D.A.)

and winding brown tunnels, which often cause premature dropping of the fruits. Infested fruits have very little market value. Larval development requires from two weeks in drops of early maturing varieties to three or more months in hard winter apples. When fully developed they leave the fruits, crawl into the soil, and transform to puparia. One generation per year is typical; in some areas a partial second brood of adults appears late in the season. Most of these begin to emerge late in September and are of little importance since practically all the fruit is harvested except the hard winter varieties which are unattractive to the flies for oviposition.

Recorded parasites are *Opius melleus* Gahan, which attacks the larvae, and *Patasson conotracheli* (Gir.), which attacks the eggs. No predators of importance have been indicated.

Where economically feasible, the systematic destruction of infested dropped apples and the elimination of species of hawthorn in the vicinity of the orchard are considered valid practices for control. Apple maggots in fruits may be killed by cold-storaging the fruit at 32° F. for a period of forty days.

The standard chemical control measure is the application of 3 pounds of lead arsenate in 100 gallons of water in the third, fourth, fifth, and sixth, cover sprays, a period from mid-June to August. This chemical is more effective in wet periods. Sprays containing 2 pounds of 50% DDT wettable powder in 100 gallons of water have also been satisfactory. Timing of these sprays is designed to kill the adults before they deposit their eggs. Other recommended materials are carbaryl, diazinon, guthion, and methoxychlor or combinations of these.

References: *U.S.D.A. Tech. Bul.* 66, 1928; *Cir.* 600, 1941; *J. Econ. Ent.*, 40:183–189, 1947; 44:147–153, 1951; 47:479–485, 1954; 57:163–164, 1964; *Conn. Agr. Exp. Sta. Bul.* 552, 1952; 604, 1957.

APPLE CURCULIO

Tachypterellus quadrigibbus (Say), Family Curculionidae

This native North American insect is found from Canada to Florida and westward to the Mississippi River. Common hosts are apple, pear, crab apple, and hawthorn. Knotty malformed fruits are caused by the feeding and egg punctures, and represent a large proportion of the loss from the curculio. Larval feeding takes place within the fruits. It is probable that, in orchards where the plum curculio does important damage, the work of the apple curculio often occurs and passes unnoticed. The injuries, except those resulting from egg punctures, are so similar that they are readily differentiated only by an experienced person.

The variety *magnus* has been found in West Virginia but is normally present in states near the Mississippi River and thence to the Great Plains region. A related species is *T. consors* Dietz, which is distributed from the Rocky Mountains to the Pacific Coast; it is, however, of little importance as a pest.

The adult resembles the plum curculio, but is slightly smaller-bodied with a much longer snout which protrudes forward. Larvae also resemble those of the plum curculio but are thicker in the abdominal region (Fig. 384).

There is only one generation of the apple curculio each year. Eggs are laid during May and June in cavities hollowed out in the fruits by the long snouts of the adult females. Hatching occurs in a week, the larvae developing near the center of the fruits and in about twenty days transforming to pupae. New adults appear approximately seven days later, do some feeding

Fig. 384. The apple curculio, *Tachypterellus quadrigibbus* (Say); adult and larva. (Brooks.)

on maturing fruits, and soon enter hibernation in debris on the ground under the trees.

The spraying program advocated for the plum curculio (p. 443) adequately controls this insect.

References: *N.Y. Agr. Exp. Sta. Tech. Bul.* 240, 1936; *W. Va. Agr. Exp. Sta. Bul.* 126, 1910.

PLUM CURCULIO

Conotrachelus nenuphar (Herbst), Family Curculionidae

Widely distributed east of the Rocky Mountains, this native American insect is an important pest of stone fruits. It also attacks apple, pear, quince, and related hosts. In apple, the worms reach their full growth only in fruits that fall prematurely.

Injury to all hosts results first from the spring feeding of the adults, then from the female egg punctures, next from the feeding of the larvae within the fruits, and finally from the early fall feeding of the beetles.

The adult is a hard-bodied snout beetle, nearly $\frac{1}{4}$ inch in length, brown with faint gray markings, and has four humps on the elytra. The fully grown larva is legless, about $\frac{3}{8}$ inch long, curved, and white with a brown head (Fig. 385).

The beetles hibernate in protected places in or near the orchard and appear with the early foliage in the spring. They feed for a period of five or six weeks during which eggs are placed in fruits that have attained sufficient size. The white eggs are laid in cavities in the fruits made by the mouthparts; the fruits are also marked by crescent-shaped cuts just beneath. Even when the larvae fail to develop, which often occurs in apples that

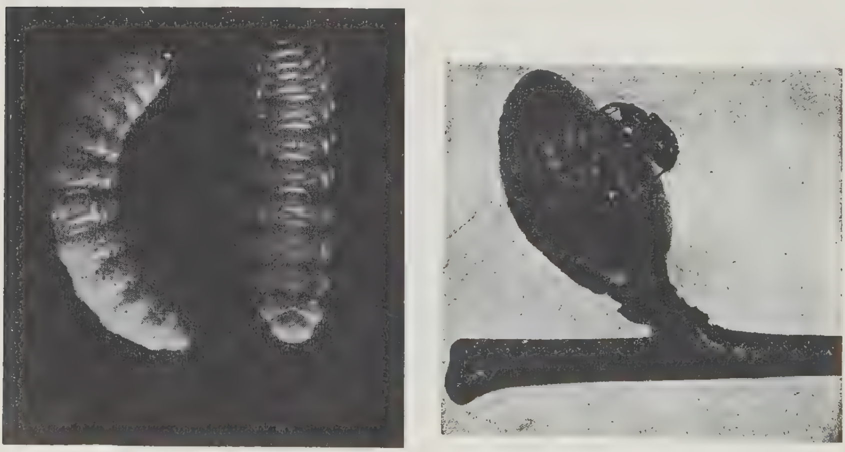


Fig. 385. Larvae and adult of the plum curculio. (U.S.D.A.)

Fig. 386. Injury caused by the plum curculio. Egg punctures in plums.

remain on the tree, the oviposition scars remain and reduce the quality of the fruit. Both oviposition and early adult feeding punctures cause abnormal growth of fruits (Fig. 386). Hatching requires about five days, and the larvae feed for two or three weeks in the fruits before they are fully developed. Mature larvae leave the fruit through a clean-cut exit hole, free of frass or webbing, drop to the ground, and pupate in the soil. The beetles emerge in a month, and either feed on fruits for a period and then go into hibernation or lay eggs which develop into a second generation, the latter taking place in the Georgia peach belt. Woodland areas and brushy fence rows adjacent to orchards serve as ideal hibernating quarters.

Natural control of the curculio results from winter mortality, attacks of birds and other predators, and from parasites. An ichneumon wasp, *Tersilochus conotracheli* (Riley), attacks the larvae in the fruit, as does the parasite, *Triaspis curculionis* (Fitch). An egg parasite, *Patasson conotracheli* (Girault), is of some importance, too. Both beetles and larvae are also attacked by a fungus, *Isaria anisopliae* Metch.

Mechanical control by jarring the sluggish beetles from the trees in the morning and capturing them on sheets was an early method of control, which is occasionally employed even now in peach orchards in the South. Destruction of all infested fruits which fall to the ground is of value, especially in the two-generation areas. Hogs have been put in orchards for this purpose. Cultivation of the soil containing the pupae destroys many of them.

In apple and pear orchards the commonly recommended insecticides are lead arsenate, dieldrin, guthion, or parathion applied as sprays at the pink, petal-fall, first and second cover spray periods. Where curculio has not been a problem the pink spray may be omitted. On peaches, plums, and cherries the following additional insecticides have been employed with

satisfactory results: malathion, EPN, and methoxychlor, all formulated as wettable powders. In the two-generation areas, applications three to five weeks before the expected date of harvest may be needed. Dieldrin must not be applied later than the second cover spray. Parathion, guthion, or malathion are preferable in orchards where mites, aphids, leafrollers, and oriental fruit moth are problems. Methoxychlor has been generally less effective but is useful near harvest because the danger is less from poisonous residues. Treating the soil under the trees with aldrin, dieldrin, or heptachlor at 2 pounds per acre has given excellent control of curculio and is a recommended practice in peach orchards in some regions.

References: *Conn. Agr. Exp. Sta. Bul.* 301, 1930; 552, 1952; 575, 1953; *Del. Agr. Exp. Sta. Bul.* 193, 1935; *Va. Agr. Exp. Sta. Bul.* 297, 1935; *N.Y. Agr. Exp. Sta. Bul.* 684, 1938; *U.S.D.A. Tech. Bul.* 188, 1930; *Farmers' Bul.* 1861, 1954; *J. Econ. Ent.*, 47:909–912, 1954; 51:131–133, 1958; 53:439–441, 1960; *Ohio Agr. Exp. Sta. Res. Bul.* 930, 1963.

APPLE LEAFHOPPERS

Order Homoptera, Family Cicadellidae

Many species of leafhoppers attack apple. They are widely distributed throughout the apple-growing areas of the United States and Canada. Some have a much greater distribution, occurring on many other hosts. Damage is caused by removal of plant sap by the piercing-sucking mouthparts of both nymphs and adults. The resulting injury interferes with the normal photosynthetic processes of the plant, causing smaller, poorer quality fruits, which are often speckled with excrement. Foliage often becomes whitened as the leafhopper population increases. Some comments on the life cycle, distribution, and habits of the more prevalent species follow.

White Apple Leafhopper, *Typhlocyba pomaria* McAtee, is widely distributed and has often been confused with the rose leafhopper. It is frequently the dominant species and is especially abundant in the central and eastern areas of the United States. Winter is passed in the egg stage underneath the bark of small branches. Hatching occurs near the pink stage, and the white adults appear in June and again in late August and September; there are two generations each year.

Rose Leafhopper, *Edwardsiana rosae* (L.), resembles *T. pomaria* and is also widely distributed (Fig. 387). It is the most important species in the Pacific Northwest. It also winters in the egg stage in the bark of trees, appearing as small raised blisters. Hatching occurs in April and May, and three to six weeks are required for nymphal development. First-generation adults appear in June, the second in late July and August. Adults may live for nearly two months. Besides apples, roses are seriously injured in some localities.

Apple Leafhopper, *Empoasca maligna* (Walsh), is a green species,

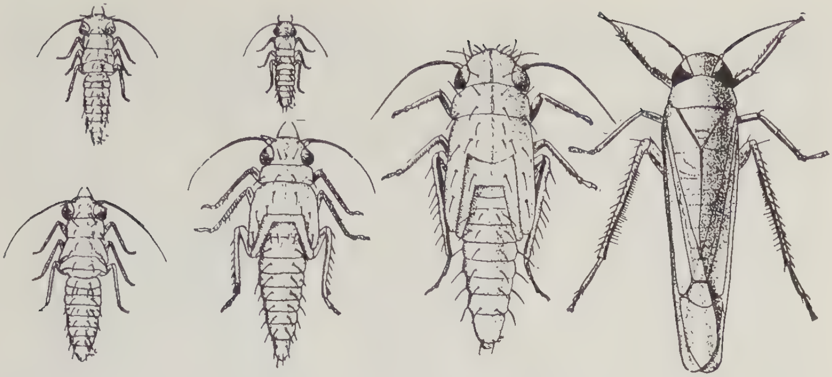


Fig. 387. The rose leafhopper, *Edwardsiana rosae* (L.). (Childs, Ore. Agr. Exp. Sta.)

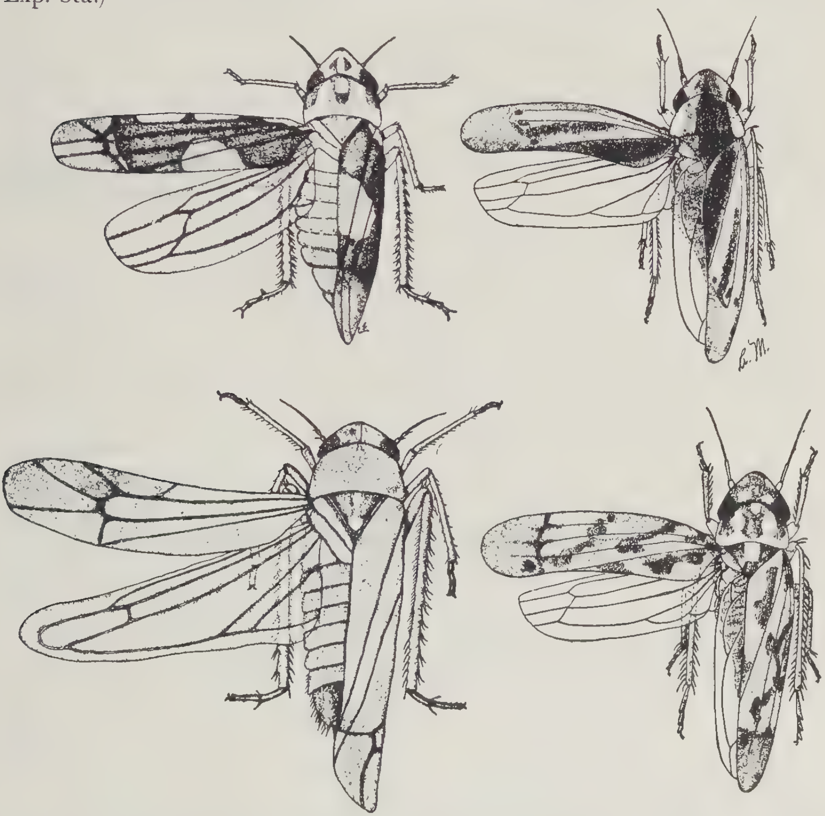


Fig. 388. Apple leafhoppers: *Erythroneura hartii* (Gillette) and *E. lawsoniana* Baker, (below) *Empoasca maligna* (Walsh) and *Erythroneura omani* Beamer. All enlarged. (Ackerman, U.S.D.A.)

slightly larger in size (Fig. 388). Its range extends from the north central states into the Pacific Northwest. Overwintering eggs are found in the bark of two- or three-year-old branches. These hatch in April or May, and the light green nymphs develop into adults three or more weeks later. Egg-laying continues until late July; the eggs remain in the bark until the following spring. This leafhopper has only one generation annually and does not become as numerous as the white species.

Potato Leafhopper, *Empoasca fabae* (Harris), has been discussed as a pest of potatoes, beans, and alfalfa (p. 292). This small green species occasionally attacks apple, and is often a pest in nurseries. It overwinters only in the South, re-occupying its northern range by annual migration. The destructive range is almost entirely east of the Rocky Mountains. There may be three or more generations on apple, depending on the latitude.

Oblique-Striped Apple Leafhopper, *Erythroneura lawsoniana* Baker, is a common species found on apple. It is opaque white with a dorsal, scarlet oblique stripe (Fig. 388). Winter is passed in the adult stage, activity beginning early in the spring, with two or three generations developing annually. Other species sometimes abundant on apple and other hosts and having similar life cycles are *E. hartii* (Gillette), *E. omani* Beamer (Fig. 388), *E. dowelli* Beamer, and *E. magnacalx* Beamer.

Natural enemies include spiders, lacewings, *Orius insidiosus* (Say), and other predators in the leaf bug family. Mymarid egg parasites and dryinid adult parasites in the genus *Aphelopus* are at times of considerable importance in keeping populations checked.

Effective control can be accomplished by sprays containing 2 pounds of 50% DDT wettable powder or 1 pound of 15% parathion wettable powder in 100 gallons of water. Guthion and malathion are other recommended chemicals. Applications should be made when the species appears in abundance in a given region. If one of these insecticides is included in the spray schedule for other apple pests, special applications for leafhoppers are not necessary. A strain of *E. lawsoniana* showing resistance to DDT has been controlled by a spray of 1 pint of 40% nicotine sulfate plus 3 pounds of powdered soap in 100 gallons of water.

References: *J. Econ. Ent.*, 24:1214–1222, 1931; 47:361–362, 1954; *Conn. Agr. Exp. Sta. Bul.* 552, 1952; *Ohio Agr. Exp. Sta. Res. Bul.* 930, 1963.

APPLE RED BUGS

Order Hemiptera, Family Miridae

Two species of bugs similar in appearance and in life history do damage almost identical in character. They are the apple red bug, *Lygidea mendax* Reuter, and the dark or false apple red bug, *Heterocordylus malinus*

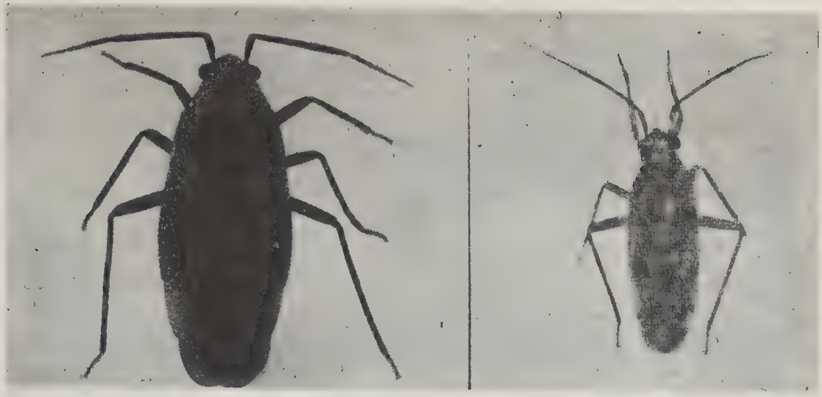


Fig. 389. The apple redbugs, (left) *Heterocordylus malinus* Reuter, and (right) *Lygidea mendax* Reuter.

Reuter. They have been injurious primarily in the north central and northeastern states and in Canada. Nearly all varieties of apples are attacked, Rome Beauty, and Red Delicious perhaps least. Both species are bright red in the nymphal stage; the adults are orange-red with darker markings (Fig. 389). Their length is about $\frac{1}{4}$ inch. In size and form they resemble tarnished plant bugs.

Eggs of the red bugs are found on the bark, where they pass the winter. At apple-blooming time they hatch, and the young bugs puncture the fruits, just as they are forming, with their piercing-sucking mouthparts. Growth is arrested at these feeding punctures, causing stunted, dimpled, and malformed fruits, sometimes with russeted spots that become especially evident near maturity. Foliage feeding occurs but is considered of little importance. By June, the adult stage is reached, and about ten days later egg-laying commences and continues into July. Usually all adults have disappeared by August.

Injury by these bugs may be prevented by including at the petal-fall period wettable powders containing either 2 pounds of 50% DDT or 2 pounds of 15% parathion in each 100 gallons of spray. Dormant oils in the spray program are of some value against the overwintering eggs.

References: *N.Y. Agr. Exp. Sta. Bul.* 716, 1946; *Ohio Agr. Exp. Sta. Res. Bul.* 930, 1963.

EYE-SPOTTED BUD MOTH

Spilonota ocellana (D. and S.), Family Olethreutidae

This insect, also called the bud moth, is said to have been imported from Europe over 100 years ago. It is now distributed in all the principal apple-producing sections of this continent, but it has been a serious pest only in the northeastern and northwestern states.

Fig. 390. The eye-spotted bud moth, *Spilonota ocellana* (D. and S.), and its injury. (W. E. Britton.)

The moth is somewhat smaller than the codling moth, dark brown with a light-colored band which shows best when the wings are in a normal resting position (Fig. 390). The fully grown larva is nearly $\frac{1}{2}$ inch in length, brown with a shiny black head and thoracic shield, and a paler mid-dorsal stripe.

Eggs are laid during the midsummer period, singly or in small groups on either upper or lower leaf surfaces. Several days later hatching takes place, and the larvae feed on the leaves, usually in shelters of leaves and silk. Cull apples result from occasional feeding on fruits that are in contact with the leaf shelters. Early in the fall the partly grown larvae form silken hibernating shelters on twigs at the base of spurs or in crevices in the bark of larger branches. Here they remain inactive until the following spring, when activity is resumed as the first buds are swelling. They often are found feeding inside the buds or in rolled or twisted leaves. In shelters formed by crumpled leaves and silk they transform to pupae in early summer, and new adults begin emerging by mid-June, thus completing the single-generation life cycle.

The cyclic nature of bud moth activity is caused by the fourteen or more

recorded parasites and predators that play an important role in control, along with environmental factors, particularly frosts.

Where an infestation is serious good control of larvae is secured with a dormant spray containing 4 quarts of a 20% emulsifiable concentrate of the sodium salt of 4,6-dinitro-o-cresol (DNOC) in 100 gallons of water. Delayed dormant, calyx, first cover, and midsummer sprays of parathion, guthion, and malathion are effective against larvae and adults.

References: *U.S.D.A. Bul.* 1273, 1924; *Conn. Agr. Exp. Sta. Bul.* 552, 1952; *J. Econ. Ent.*, 55:930–934, 1962.

FRUIT-TREE LEAF ROLLER

Archips argyrospilus (Walker), Family Tortricidae

This native leaf roller occurs in the northern half of the United States, from coast to coast, and in Canada as well. Although it is commonly discussed as an apple pest, it injures all the orchard fruits and may require special control measures on any one of them. Early larval feeding on blossom buds may prevent setting of fruits. Serious damage results where the leaves are held against the fruits with silk, the larvae feeding within (Fig. 391). Foliage injury is of less consequence although it may also be severe.

The adult moth is slightly larger than the codling moth, brown with variable lighter markings on the front wings (Fig. 392). The slender, pale green larva reaches a length of $\frac{3}{4}$ inch; it has a black head and a black spot on the thorax just back of the head. Eggs are laid in gray, compact oval masses on the bark of twigs and branches, each mass containing up to 100

Fig. 391. Damage caused by the fruit-tree leaf roller. (Hough, Va. Agr. Exp. Sta.)

Fig. 392. The fruit-tree leaf roller, *Archips argyrospilus* (Walker). (Pettit, Mich. Agr. Exp. Sta.)

or more. They are coated with a secretion from the moth which hardens and serves to protect the eggs.

The insect winters in the egg stage and hatching occurs when the buds begin to open. The larvae feed on the buds, blossoms, leaves, and fruits, becoming fully grown in June and transforming to pupae inside rolled or folded leaves. In about two weeks the moths begin emerging and shortly afterwards lay their eggs and die, only one generation developing annually.

Many parasites attack the various life stages of the leaf roller, but their combined effect is not always sufficient to keep it checked.

The most effective means of control is application of a spray containing 2 pounds of 50% DDT wettable powder in 100 gallons of water at the pink, calyx, or first cover period to kill the newly hatched larvae. If guthion, parathion, or lead arsenate are applied during these same periods they will effect control. Thorough coverage in the dormant period with an emulsion containing 3% superior oil has killed a high percentage of the overwintering eggs. This application should be made during the first period of settled mild weather in the spring. It should not be done just before a rain or when the temperature is likely to drop within a few days to 25° F. or below.

Reference: *U.S.D.A. Cir.* 270, 1950.

OBLIQUE-BANDED LEAF ROLLER

Choristoneura rosaceana (Harris), Family Tortricidae

Of less importance as an apple pest than other species in the genus, this leaf roller may be found attacking foliage in the spring, and fruit as well as foliage in the summer and fall. Widely distributed from Maine to California, it feeds on many plants and has at times been a pest in greenhouses, attacking roses. The young light green, black-headed larvae mine the leaves first, then feed inside rolled leaves tied with silk. Adults are brown, with three oblique darker bands on the front wings, and a wingspread of nearly 1 inch. Further observations are needed to determine whether the winter is passed as eggs or as partly grown larvae. DDT dusts or sprays are recommended to control it.

RED-BANDED LEAF ROLLER

Argyrotaenia velutinana (Walker), Family Tortricidae

The red-banded leaf roller (Fig. 393) is a native insect which has become injurious in the section of the country north of the Ohio and east of the Mississippi Rivers. It is probably most abundant in the so-called Cumberland-Shenandoah apple region, but it occurs in other widely scattered localities. Host plants include apple, cherry, plum, peach, grape, several of the small fruits, vegetable crops, ornamentals, and weeds.

Larvae fed on foliage, often inside rolled or folded leaves held in place

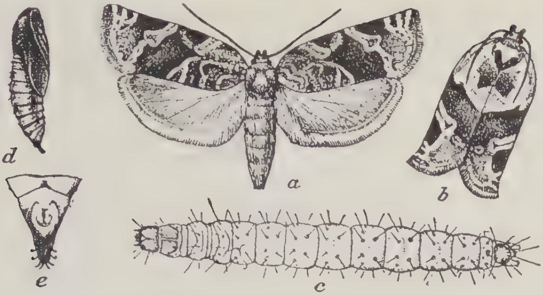


Fig. 393. Red-banded leaf roller, *Argyrotaenia velutinana* (Walker): *a,* female moth; *b,* moth with wings folded at rest; *c,* larva, dorsal view; *d,* pupa, lateral view; *e,* tip of abdomen of pupa, showing abdominal hooks. (U.S.D.A.)

Fig. 394. Fruit injury caused by the red-banded leaf roller. (Hough, Va. Agr. Exp. Sta.)

by silken threads. When leaves adjacent to fruits are tied with silk, the larvae cause many blemish marks by eating patches off the surface. Such feeding rarely extends to a depth of $\frac{1}{4}$ inch, but it may be an inch or so across the area (Fig. 394).

The adult is about the size of the codling moth, brown with a broad reddish band and other irregular light markings on the fore wings. The green larva is comparatively slender and about $\frac{5}{8}$ inch in length.

Winter is passed as a pupa inside a silken cocoon under leaves or other objects on the ground. Moths begin emerging in the spring and deposit their eggs in flattened clusters usually on the bark of the trees. These hatch

near the petal-fall period, and the larvae feed and develop, then pupate and emerge as adults in July. These soon lay eggs, and a second generation develops through late July and August. Three to four overlapping generations have been observed in southern areas.

Good control has resulted from applying sprays of lead arsenate, parathion, guthion, mevinphos, TDE, or carbaryl in the first, second, fifth, and sixth cover sprays. Lead arsenate is generally recommended only for early season application and mevinphos and carbaryl only late in the season. Parathion and guthion are the recommended pesticides where mites, aphids, and curculio are also problems. Growers employing a lead arsenate spray schedule are usually not troubled with this pest. Where the infestation is light, good control has been obtained by including 3 pounds of lead arsenate in the first or second, and the fifth cover sprays.

References: *Va. Agr. Exp. Sta. Bul.* 259, 1927; *Ohio Agr. Exp. Sta. Res. Bul.* 930, 1963; *J. Econ. Ent.*, 54:88–91, 1961.

PEAR PSYLLA

Psylla pyricola **Förster, Family Psyllidae**

The pear psylla, of European origin, was first found in Connecticut in 1832, and has since spread throughout the area east of the Mississippi River, wherever pears are grown. It was discovered in the Pacific Northwest in 1939, and is now known to occur in most of the pear-growing regions in the West.

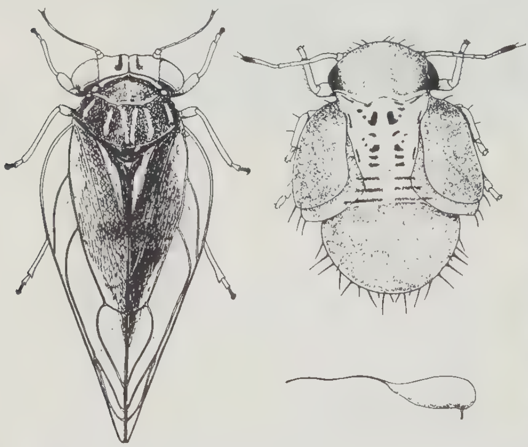


Fig. 395. The pear psylla, *Psylla pyricola* Förster; adult, nymph, and egg. (Britton.)

Fig. 396. Eggs of the pear psylla. (Mich. Agr. Exp. Sta.)

Injury is limited to pears. Honeydew excreted by the piercing-sucking nymphs and adults drops on the foliage and fruit and a sooty fungus develops in it. This results in black spots on the foliage and lower quality fruits. Severe infestations may cause leaf drop and prevent normal bud formation. This insect is the vector of a virus pathogen causing the disease known as "pear decline."

Adults are approximately $\frac{1}{10}$ inch in length and resemble tiny red-brown cicadas, with four membranous wings (Fig. 395). These overwinter concealed in crevices on the trunks of trees and in shelter furnished by the ground cover or other material. Emergence takes place during the first warm days in the spring, and egg-laying begins soon afterwards. The elongate, white-to-yellow eggs are deposited in the crevices about the buds, and, after the foliage is out, on the leaves (Fig. 396). Hatching takes place in ten to thirty days. The flattened nymphs pass through five instars before reaching the adult stage. The nymphs are yellow at first, becoming green as they increase in size, with the final instar almost black. At least four generations may develop each year. Second-generation adults, and those produced later in the season, are smaller and lighter in color than those of the first generation. They were once considered a different species.

An application of oil emulsion spray in early spring while the trees are still dormant kills many adults and eggs. In some areas these dormant oils are applied in combination with ethion, trithion, or lime-sulfur. Summer generations may be controlled by one or two spray applications of one of the following insecticides: rotenone plus summer oil, summer oil alone, guthion, malathion, parathion, Perthane, diazinon, Dilan, dieldrin, or nicotine sulfate.

References: *Conn. Agr. Exp. Sta. Cir.* 143, 1941; *U.S.D.A. Cir.* 270, 1950; *Agr. Handbook* 290, 1965; *Calif. Agr.*, 17:14–15, 1963; *Calif. Agr. Exp. Sta. Leaflet* 71, 1966.

PEAR LEAF BLISTER MITE

***Eriophyes pyri* (Pagenstecher), Family Eriophyidae**

Introduced from Europe about 1870, this tiny mite is now generally distributed in North America. It attacks buds, foliage, and fruits of pear, apple, mountain ash, service berry, and cotoneaster. Its feeding causes the formation of galls or blisters on the leaves. These blisters are yellow to green at first, becoming red, and finally black on the leaves of pear (Fig. 397). Fruits may be russeted or deformed and will often crack open.

The white, tapered, four-legged mites are exceedingly small, less than $\frac{1}{100}$ inch in length (Fig. 398). They winter beneath the bud scales, and become active and lay eggs when the buds begin to swell in warm spring weather. They produce their characteristic injury by feeding and burrowing into the leaf tissue. A succession of overlapping generations develops

Fig. 397. The pear leaf blister mite, *Eriophyes pyri* (Pagenstecher). (N. Y. Agr. Exp. Sta.)

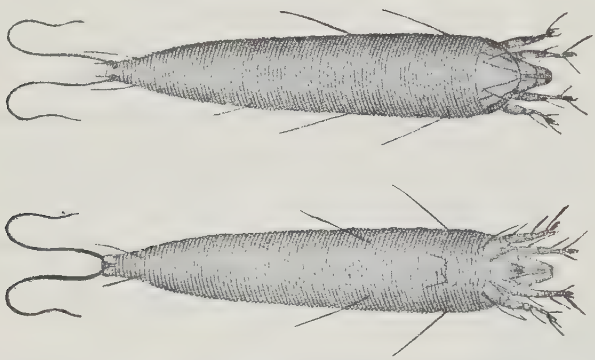


Fig. 398. The pear leaf blister mite, dorsal and ventral views ×300. (Nalepa.)

throughout the summer, with migration to other leaves and fruits occurring. With the approach of cold weather the mites return to the buds, where they hibernate beneath the scales.

There is evidence that the form attacking apples and related plants is a distinct species. Further investigation is needed to clarify this point.

Lime-sulfur sprays have long been the standard treatment for this pest. A dormant application at a dilution of 1 gallon to 10 or 12 gallons of water has given effective control. Good control has also been obtained by applying it in the fall as soon as the leaves have dropped. Three per cent oil emulsions are effective if applied in the delayed dormant period during warm weather. In the Pacific Northwest oil emulsions are combined with lime-sulfur and applied just as the buds are swelling in the spring. Other

treatments are demeton for spring and diazinon for fall application, whereas carbaryl or endosulfan may be applied at either period.

References: *N.Y. Agr. Exp. Sta. Cir.* 51, 1916; *U.S.D.A. Cir.* 270, 1950; *J. Econ. Ent.*, 56:664–666, 1963.

PEAR THRIPS

Taeniothrips inconsequens (Uzel), Family Thripidae

The pear thrips were first noticed as pests in California in 1904, and since that time have become destructive in New York and adjacent states. In the western infestations they attack pear, plum, prune, cherry, apricot, apple, almond, and other plants, but in the East they have been primarily destructive to pear.

The dark brown adult is scarcely $\frac{1}{16}$ inch in extreme length and of the form illustrated (Fig. 399). The nymphs are smaller in size, wingless, and somewhat lighter in color, often almost white. Both nymphs and adults feed by rasping the surface of plant tissues and then sucking out the juices.

Thrips spend several months in the soil as nymphs. Adults emerge in early spring and begin to feed, largely in the opening buds of the hosts. After feeding for three weeks they begin laying tiny white eggs in the tissues of foliage and buds. Two weeks later the eggs hatch, and the young thrips feed and develop on foliage and fruits. After three weeks they drop to the ground, crawl into the soil to a depth of several inches and remain inactive, changing in late autumn to adults, which emerge the following spring. The most serious injury is caused by the adults feeding in early spring on the developing buds, causing deformed leaves and blossoms, and thus a reduction of the crop. Both nymphs and adults may cause young fruits to be scabbed, russeted, and deformed. Pear thrips are thus active on the trees for only about two months in the spring and are dormant in the ground the rest of the year. Bean thrips (p. 312) also attack pears in some regions.

Effective control can be accomplished by thoroughly spraying the trees

Fig. 399. Life stages of pear thrips, *Taeniothrips inconsequens* (Uzel). (Foster and Jones, U.S.D.A.)

with DDT during the first warm weather after many of the buds show green. Mix 2 pounds of 50% wettable powder or 1 pint of 25% emulsifiable concentrate in 100 gallons of water. If needed, additional sprays may be applied when the blossom buds begin to show white and at petal-fall. A dust formulation containing 5% DDT is also effective. There is the possibility that thrips can be controlled with insecticides applied to the soil just before the nymphs enter it.

References: *U.S.D.A. Cir.* 270, 1950; *Agr. Handbook* 290, 1965.

PEAR SLUG

Caliroa cerasi (L.), Family Tenthredinidae

Of European origin, this widely distributed chewing insect (Fig. 400) skeletonizes the leaves of pear, cherry, plum, quince, and occasionally apple. Because in some areas it becomes quite abundant on cherry trees, it is also known as the cherry "slug."

In their earlier instars the larvae are green-black, elongate, slim, and slug-like, with very little evidence of legs (Fig. 401). In the last instar they transform to typical sawfly larvae, nearly $\frac{1}{2}$ inch in length, and resemble green-orange caterpillars. Their bodies are enlarged near the head and taper posteriorly. The adult is a glossy black, four-winged sawfly, scarcely as large as a house fly.

The winter is passed in the soil inside a cocoon. Adults emerge in the spring after the trees are fully leaved; they deposit their eggs in slits in the leaves by means of a saw-like ovipositor. These hatch a week or more later. Larval development is completed in less than a month, and pupation takes

Fig. 400. The pear slug, *Caliroa cerasi* (L.); adults. (Severin, S. D. Agr. Exp. Sta.)

Fig. 401. Injury by pear slug larva. (U.S.D.A.)

place in cocoons in the soil. In late July adults of the second generation appear and lay eggs. On hatching, the larvae develop to maturity, enter the soil, and spin cocoons in which they overwinter.

Control is readily accomplished by spraying about fifteen days after bloom with one of the following insecticides in 100 gallons of water: 2 pounds of lead arsenate, 2 pounds of 50% DDT wettable powder, 1.5 pounds of 15% parathion wettable powder, or 1 pound of 25% EPN wettable powder. When any one of these chemicals is applied in a spray program for controlling other insects, no special applications are needed for the pear slug.

PEAR MIDGE

Contarinia pyrivora (Riley), FAMILY CECIDOMYIIDAE

The pear midge is an introduced insect, present in the northeastern states for over fifty years. The adult is a very small, mosquitolike fly (Fig. 402). It emerges from the overwintering puparia in the soil and lays eggs in the swelling blossom buds of pear trees. The resulting creamy white-to-pale orange maggots feed inside the young fruits, causing them to be ill-shaped and to drop prematurely. In five weeks the maggots reach full development, drop to the ground, and enter the soil where transformation to puparia occurs; there is only one generation each year.

Spraying the entire tree, including the trunk, with 2 pounds of 50% DDT wettable powder in 100 gallons of water just as the sepals separate from the buds, and again about seven days later, will give satisfactory

Fig. 402. The pear midge, *Contarinia pyrivora* (Riley). (Slingerland.)

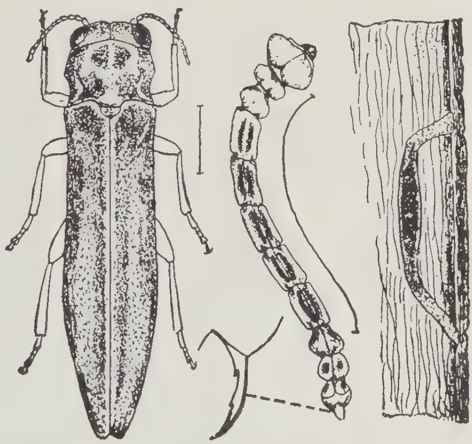


Fig. 403. The sinuate pear tree borer, *Agrilus sinuatus* (Oliv.). (J. B. Smith.)

control of this insect. The spray kills the newly emerging flies before they lay their eggs.

Reference: *N.Y. Agr. Exp. Sta. Tech. Bul.* 247, 1937.

SINUATE PEAR TREE BORER

Agrilus sinuatus (Oliv.), Family Buprestidae

This insect occasionally attracts notice, but it is only a pest of importance in limited areas. Injury has been reported from Ohio, New York, New Jersey, and adjoining states. It is primarily a pest of pear, but mountain ash, cotoneaster, and hawthorn may also be attacked. Damage is caused by the larvae boring just beneath the bark, their slender sinuate galleries being found in both the trunk and the branches (Fig. 403).

The adult is a bronzy, slender, buprestid beetle, nearly $\frac{3}{8}$ inch in length; the larva is elongate and slender, with the characteristic flattened head much reduced in width. Adults emerge in early summer and feed sparingly on the foliage before mating and laying their eggs. The larvae feed for two summers, hibernating each winter, then pupating the following spring and emerging as adults. There is one generation every two years.

Orchards receiving sprays containing lead arsenate, organophosphorus compounds, or DDT are not troubled by this insect. Sprays should be timed to kill the emerging adults before they lay their eggs.

Reference: *N.Y. Agr. Exp. Sta. Bul.* 648, 1934.

MISCELLANEOUS INSECTS ATTACKING APPLE AND PEAR

Lesser Bud Moth, *Recurvaria nanella* (Hbn.), is a gelechiid species imported from England where it is a minor pest of apple and pear. In this country it may also attack the stone fruits. In some regions this moth is said to be more abundant on apple than the eye-spotted bud moth. Adults are mottled gray moths; the larvae are green-brown caterpillars which attain a length of $\frac{1}{2}$ inch or more. The larvae feed on foliage until fall, hibernate, and continue feeding in the spring. At this time the buds are attacked, and damage may be severe. Pupation takes place in midsummer, and adults emerge soon afterwards and deposit eggs. Sprays recommended for the eye-spotted bud moth also control this species.

Apple Flea Weevil, *Rhynchaenus pallicornis* (Say), attacks apple, hawthorn, crab apple, elm, hazelnut, and choke cherry. Ornamental crab apples frequently are damaged. This insect may be locally injurious in the area from the Mississippi River eastward and north of the Ohio River. The nearly black adults are snout beetles, almost $\frac{1}{10}$ inch in length. They pass the winter under the duff on the ground. They become active and feed on newly opening buds and leaves in the spring. Soon eggs are laid on the leaves which hatch into legless white larvae. The larvae mine the leaves,

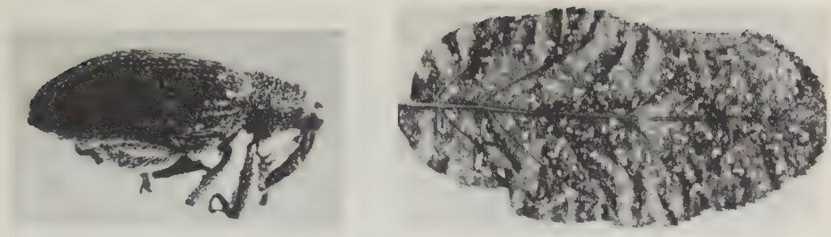


Fig. 404. The apple flea weevil, *Rhynchaenus pallicornis* (Say); adult, and injured leaf. (Mich. Agr. Exp. Sta.)

especially at the edges, becoming fully grown in two or more weeks and pupating within the mines. By late May or early June new adults appear, which feed for nearly a month, causing damage similar to that of flea beetles (Fig. 404). They then enter hibernation quarters and remain inactive until the following spring. Only one generation develops each year.

Good control has been obtained by spraying at the prepink or pink periods with wettable powders containing either 2 pounds of 50% methoxychlor, or DDT, or 2 pounds of 15% parathion in 100 gallons of water. These early sprays of parathion have been known to injure Cortland and McIntosh varieties.

Apple Seed Chalcid, *Torymus varians* (Walker), is an interesting pest species of the superfamily Chalcidoidea. The tiny wasps oviposit in apples and related fruits, causing a dimpled condition on the surface resembling plant bug injury. The larvae feed on the seeds. The range of the insect is northeastern United States extending into Canada. It has not been injurious in orchards receiving a regular spray program of present-day insecticides for codling moth and plum curculio.

Lesser Appleworm, *Grapholitha prunivora* (Walsh), is the young of a congener of the codling moth, which it somewhat resembles. The larvae are smaller and more reddish than those of the codling moth. Early feeding by the worms on the foliage is relatively unimportant, the serious injury occurring late in the summer when the larvae mine the skin of the fruits and ruin their market value (Fig. 405). The injury resembles that done by the red-banded leaf roller, except that the latter consumes the skin, whereas the lesser appleworm feeds beneath it. There are two generations per year. Apples thoroughly sprayed for codling moth control do not suffer injury from this species. The insect is eastern in distribution.

Leaf Crumpler, *Acrobasis indigenella* (Zeller), is a small brown moth with mottled wings (Fig. 406), the larvae of which feed on the foliage of apple, pear, quince, plum, and cherry. Attention is usually attracted to the insects by the ragged dark cocoons made of leaves and silk, inside which

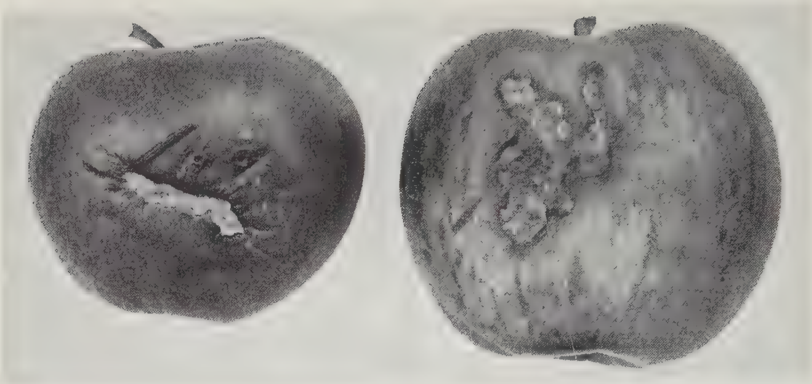


Fig. 405. Fruit injury caused by the lesser appleworm, *Grapholitha prunivora* (Walsh.) (Quaintance, U.S.D.A.)

partly grown larvae hibernate. They become active in the spring and feed on the foliage, carrying these cases or cocoons with them, like the bagworms. Development is completed by June and adults appear a few weeks later. Only a single generation is produced each year. The insect is widespread in the north central and eastern states, but damage is rarely important even in unsprayed orchards. If control measures become necessary the regular orchard spray program will suffice.

Pistol Casebearer, *Coleophora malivorella* Riley, is considered a minor pest of apple. Occasionally, however, it becomes abundant and does extensive damage. Outbreaks have occurred from the Mississippi Valley eastward. The delicate gray moths have fringed wings with a spread of almost $\frac{1}{2}$ inch (Fig. 407). The orange-yellow larvae spend almost their entire lives in gray-to-brown pistol-shaped cases, which are nearly $\frac{3}{8}$ inch long when development is complete.

The winter is passed as partly grown larvae inside their cases attached to twigs or branches (Fig. 408). In early spring activity is resumed, and

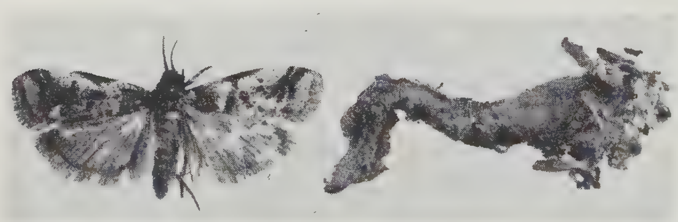


Fig. 406. The leaf crumpler, *Acrobasis indigenella* (Zeller). Note characteristic cocoon.

they feed on the leaf buds, blossom buds, and foliage, the greatest damage being done to the buds. When fully grown the larvae again fasten their cases to twigs and transform to pupae. The adult moths begin emerging two or three weeks later, usually late June, and deposit their eggs shortly thereafter. Eggs are laid on either upper or lower leaf surfaces, and hatching occurs eleven or more days later. The larvae leave the eggs at the point of attachment and burrow through the leaf, emerging on the other side a few days later with a tiny case already partly formed. Feeding continues throughout the summer with many entering hibernation by late August.

Numerous parasites and predators attack the pistol casebearer and undoubtedly are responsible for the normally low populations. Low temperatures during the brief egg-laying period also contribute to natural control. Including 2 pounds of 50% DDT wettable powder in each 100 gallons of spray at the pink and first cover eliminates this insect as a pest.

References: *W.Va. Agr. Exp. Sta. Bul.* 246, 1931; *Pa. Agr. Exp. Sta. Bul.* 406, 1941; *Ohio Agr. Exp. Sta. Res. Bul.* 930, 1963.

Fig. 407. Adults of the pistol casebearer, *Coleophora malivorella* Riley. (Slingerland.)

Fig. 408. The pistol casebearer; young larvae, cocoon and injury to young twig, and group of cocoons.

Fig. 409. Apple leaf infested with cigar casebearers. (U.S.D.A.)

Cigar Casebearer, *Coleophora serratella* (L.), has much the same range as the pistol casebearer but has not attracted much attention in recent years. The life history and general appearance of the insect is also very similar, except that the larval case of this species is cigar-shaped. Damage to buds and leaves is caused by the chewing larvae, which feed while inside their cases (Figs. 409 and 410). Chemical control measures are those recommended for the pistol casebearer.

Green Fruitworm, *Lithophane antennata* (Walker), and related species are rather large caterpillars, usually green marked with light stripes (Fig. 411). Both adults and larvae resemble our common cutworm species. They hibernate as pupae or as adults. Eggs are laid in the spring, and the larvae feed on the foliage first and later attack the young fruits. Several fruits in the same cluster may be damaged. Injury is most frequently noticed in northern United States and southern Canada. Where orchards are sprayed at calyx and first cover with lead arsenate, guthion, or DDT for controlling other pests, fruitworms are also controlled.

Apple Leaf Skeletonizer, *Psorosina hammondi* (Riley), is a small pyralid moth with brown wings marked with white lines. The brown-green larvae feed on apple and pear leaves, sometimes skeletonizing large numbers and doing some damage to the trees. Where spraying is practiced, the insect is a rarity. Its range is in the eastern parts of the country.

European Apple Sawfly, *Hoplocampa testudinea* (Klug), was discovered on Long Island in 1939. It has spread to Connecticut, Massachusetts,

Fig. 410. The cigar casebearer, *Coleophora serratella* (L.). Note cocoons.

Fig. 411. A green fruitworm, *Lithophane antennata* Walker) (U.S.D.A.)

Rhode Island, New Jersey, New York, and British Columbia. The larvae tunnel under the skin of the fruit at first and later bore directly into the apple. The adult is a typical sawfly, $\frac{1}{4}$ inch long, dark brown above and yellow-brown beneath. The larvae are never pink, like those of the codling moth, and can be easily distinguished by their seven pairs of prolegs. Winter is passed as mature larvae in the soil. Pupation takes place in the spring, and adults emerge when apple trees first come into bloom. Egg-laying occurs during full bloom, the eggs being inserted in the flesh of the calyx cup. The larvae leave the fruit by the middle of June, enter the soil, and remain inactive until the following spring. Commercial orchards receiving chemical sprays normally applied during the pink and petal-fall periods will not be troubled by this pest.

Reference: *Conn. Agr. Exp. Sta. Bul.* 552, 1952.

Pear Plant Bug, *Neolygus communis* Knight, is a near relative of the tarnished plant bug but is slightly longer and darker, except at the tips of the wings. The bug deposits winter eggs in the bark of the host. Hatching occurs near blossoming time; the tiny nymphs feed mostly on the unfolding leaves, whereas the later instars feed very largely on the fruits. The sucking of sap causes many fruits to drop if the punctures are early and numerous. Drops of sap exude from the punctures (Fig. 412), and when these disappear the damage shows as black spots or points. As the pears grow these spots rupture, resulting in cracked corky areas and malformed fruits later

in the season. The nymphs pass through five instars, becoming adults by late June. By late July all have laid eggs and died. Control is accomplished by a petal-fall spray containing guthion, dieldrin, DDT, or parathion.

Reference: *N.Y. Agr. Exp. Sta. Bul.* 368, 1913.

Quince Curculio, *Conotrachelus crataegi* Walsh, resembles the plum

Fig. 412. The pear plant bug, *Neolygus communis* Knight; (right) adult bug; (left) nymph on young pear, which shows exudation from punctures later resulting in a deformed fruit. (N.Y. Agr. Exp. Sta.)

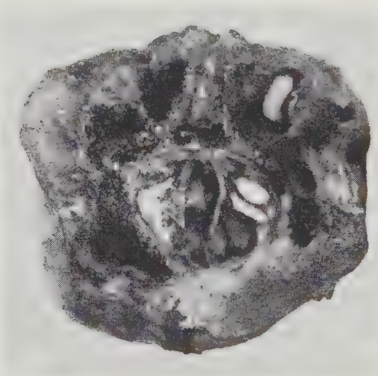


Fig. 413. The quince curculio, *Conotrachelus crataegi* Walsh; larvae in fruit. (U.S.D.A.)

curculio in appearance but differs somewhat in habits and life cycle. It is probably the most serious insect enemy of quinces, and it may also attack pears. Damage is caused by the legless white larvae feeding in the fruits (Fig. 413) and also by feeding punctures of the adults, resulting in malformations like those associated with the plum curculio. Larvae of this species winter in the soil, pupate in the spring, and transform to adults in early summer. Eggs are laid in adult feeding punctures in the fruits. On hatching the larvae spend nearly three months in the fruits before full growth is attained. Then they drop to the ground, burrow 2 or 3 inches below the surface, and remain there until the following spring. Only one generation occurs each season. Sprays of lead arsenate when the beetles appear and again when egg-laying begins have given good control. This period is from mid-June to mid-July, depending on the locality. The dosage is 3 to 4 pounds of lead arsenate in 100 gallons of water. Some of the newer insecticides recommended for plum curculio should control this insect.

Comstock Mealybug, *Pseudococcus comstocki* (Kuwana), has been a conspicuous pest of umbrella catalpa, holly, maple, boxwood, privet, mulberry, Japanese honeysuckle, and other hosts for some years. It was introduced into the United States sometime before 1918 and is now widely distributed. Since 1932 several serious infestations have been found in commercial apple orchards of the Cumberland-Shenandoah region and elsewhere. Injury results from removal of plant sap by the nymphs and adults, and from the fungus growth that develops on the copious supply of honeydew excreted by the insects. The honeydew and fungus cause much discoloration of fruits which cannot be removed even by the most effective

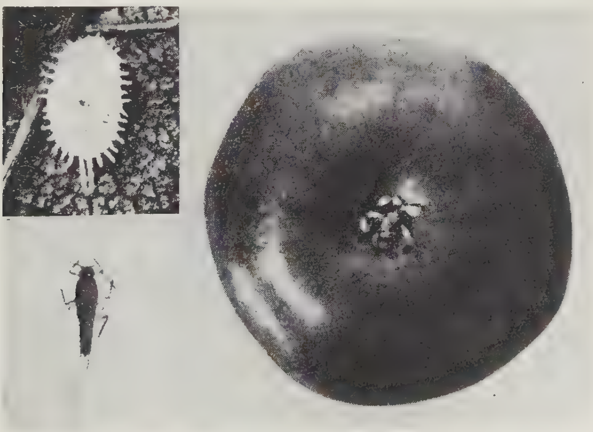


Fig. 414. Comstock mealybug, *Pseudococcus comstocki* (Kuwana). (Woodside, Va. Agr. Exp. Sta.)

fruit-washing machines. At picking time the insects themselves may remain on the fruits, especially in the calyces; it is also a problem to remove them from this area.

Winter is passed as tiny white eggs inside cottony masses, tucked in crevices of the bark. Hatching occurs about the time that leaves are unfolding in the spring. The flattened, white powdery nymphs with spiny processes on the margins of their bodies (Fig. 414) migrate over the plant and feed, becoming fully grown in a month. In northern Virginia there are three generations a season.

Excellent control in apple orchards has resulted from liberating large numbers of encyrtid parasites. Where DDT has been used for codling moth control it also has checked the mealybugs. On infested ornamental plants, malathion, guthion, or parathion at standard dosages should give satisfactory control.

References: *Va. Agr. Exp. Sta. Tech. Bul.* 29, 1925; *J. Econ. Ent.*, 44:123–124, 1951.

18

Insects Injurious to Stone Fruits

ORIENTAL FRUIT MOTH

Grapholitha molesta (Busck), Family Olethreutidae

The oriental fruit moth was introduced into this country about 1913 from Japan and was first discovered in Washington, D.C., from which it has spread over most of the United States wherever peaches are grown. Moths were first caught in baits in California in 1942, in Idaho in 1944, and in Oregon and Washington in 1945. Peach and quince are the common hosts, but occasionally apple, pear, plum, and other fruit trees are attacked, especially if infested peach trees are near-by.

The only injurious stage of the oriental fruit moth is the larvae, which tunnel into the tips of rapidly growing twigs (Fig. 415), thus preventing normal growth. New lateral shoots appear just below the point of attack giving the tree a bushy appearance. The larvae also enter the fruits and feed on the flesh, especially near the end of the growing season after twig growth becomes hardened. When fully grown they leave through holes chewed in the side of the fruit from which gummy exudates accumulate (Fig. 416).

The oriental fruit moth is closely related to the codling moth; the adults are similar in shape but somewhat smaller, $\frac{1}{4}$ inch in length, and of a dark gray coloration (Fig. 415). The larvae are white with a pink tinge, nearly $\frac{1}{2}$ inch long when fully grown, the last abdominal segment bearing a dorsal, black, five-toothed, comb-like structure which is a means of distinguishing it from codling moth larvae.

Larvae hibernate in silken cocoons on the ground, in the tree, or on other objects near-by. Pupation takes place in the spring and moths begin emerging about blooming time for peach trees. Eggs are laid on twigs and foliage, later on fruits. Early larvae tunnel into tips of tender green twigs, where they cause the characteristic wilting that indicates their presence. Full growth requires some two weeks, after which they leave the twigs,

Fig. 415. Oriental fruit moth larval damage: (left) characteristic wilted tip; (right) twig cut open showing larva in burrow. (Wood and Selkregg, U.S.D.A.); (insert) adult moth. (Garman, Conn. Agr. Exp. Sta.)

Fig. 416. Peaches injured by oriental fruit moth larvae.

Fig. 417. Parasites of the oriental fruit moth: *A*, egg parasite, *Trichogramma minutum* Riley; *B*, male; *C*, wings of female; *D*, female (wings removed) of *Macrocentrus ancylivorus* Rohwer. (Garman, Conn. Agr. Exp. Sta.)

spin silken cocoons on nearby objects, and transform to pupae. In about ten days adult emergence occurs. During the summer approximately one month is required to complete the life cycle. There are four or five generations each season in the latitude of New Jersey.

The rearing and liberation of numerous insect parasites has effected practical control in many localities. Important species are the egg parasite, *Trichogramma minutum* Riley, and the larval parasites, *Macrocentrus ancylivorus* Rohwer (Fig. 417), *M. delicatus* Cresson, and *Glypta rufiscutellaris* Cresson.

Chemicals have given outstanding control of the oriental fruit moth. The recommended materials are parathion, guthion, diazinon, EPN, DDT, and carbaryl. Three applications ten to twelve days apart, beginning at the shuck split stage, control the early generations. Two additional sprays, one about seven to eight weeks and the other three to four weeks before harvest, are usually necessary to protect the fruits. Many growers have protected their fruit from injury with only these two sprays. Parathion, guthion, and EPN are normally necessary for curculio and mite control in

the early sprays. Since these chemicals also kill the parasites, Brunson and Allen have concluded, after a five-year experiment, that five mass liberations at four-day intervals, of the parasite, *M. ancylivorus*, at the rate of six females per tree, beginning about May 20, and one preharvest spray of DDT, parathion, EPN, or guthion applied near the end of July, will give satisfactory control of the oriental fruit moth.

References: *N.J. Agr. Exp. Sta. Bul.* 455, 1928; *Conn. Agr. Exp. Sta. Bul.* 313, 1930; 575, 1953; *J. Econ. Ent.*, 47:147–152, 1954; *U.S.D.A. Tech. Bul.* 183, 1930; 1182, 1958; 1265, 1962; *Agr. Inf. Bul.* 182, 1958; 272, 1963; *Farmers' Bul.* 2205, 1964; *Calif. Agr. Exp. Sta. Leaflet* 78, 1966.

PEACH TWIG BORER

Anarsia lineatella Zeller, Family Gelechiidae

The twig borer occurs generally throughout the peach-growing areas of the United States. It has been only a minor pest in the eastern states but sometimes is a problem in the Pacific Coast states. Besides peach, it attacks plums, apricots, and almonds. The larvae injure the twigs and fruits in much the same manner as the oriental fruit moth.

The moth is very small, not exceeding $\frac{1}{4}$ inch in length, with narrow, ash gray wings fringed with hairs (Fig. 418). Larvae are small, red-brown caterpillars, with head and thoracic segments darker.

Small larvae hibernate in silk-lined cavities at various locations on branches and twigs, sometimes at the base of new shoots, under loose bark, or in crotches of branches. When growth of the trees begins in the spring these larvae emerge and bore into twigs and buds. They usually extend their tunnels only a short distance; this stops growth or kills the shoot. The feeding continues in other twigs until the larvae are fully grown, and then silken cocoons are made usually on the branches and trunk, followed by pupation. About two weeks later the adults emerge and begin laying eggs on leaves and fruits. The next brood of larvae feed on twigs and fruits;

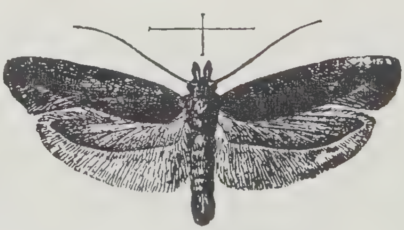


Fig. 418. The peach twig borer, *Anarsia lineatella* Zeller; adult moth with wings spread; much enlarged. (U.S.D.A.)

those which follow feed almost entirely in the fruits. There are one to four generations each season, depending on locality.

Natural enemies include a parasitic wasp, *Copidosoma pyralidis* Ashmead, the predaceous thrips, *Leptothrips mali* Fitch, and the predaceous mite, *Pyemotes ventricosus* (Newport).

The twig borer is not a problem in orchards sprayed each year at the delayed dormant period with 10 gallons of liquid lime-sulfur in each 100 gallons of water. A 3% oil emulsion has given almost as good control. Lime-sulfur is not recommended for apricot trees because of foliage injury. If no dormant sprays are applied, it is necessary to use parathion, DDT, basic lead arsenate, diazinon, guthion, endosulfan, or carbaryl at the pink-bud or petal-fall stages. Basic lead arsenate is inferior to the other chemicals, but it has given what is considered satisfactory control in California. Parathion or diazinon combined with dormant oil sprays have effectively eliminated hibernating larvae.

References: *J. Econ. Ent.*, 44:935–939, 1951; *U.S.D.A. Agr. Inf. Bul.* 272, 1963; *Calif. Agr. Exp. Sta. Cir.* 449, 1955; *Leaflet* 78, 1966.

PEACH TREE BORER

Sanninoidea exitiosa (Say), Family Aegeriidae

The peach tree borer is a native American insect which attacks plum, prune, cherry, almond, apricot, and nectarine but is important mainly on peach. Injury is caused by the larvae boring just beneath the bark near the ground level, destroying the cambium and often girdling the trunk or roots. It is found throughout the United States wherever peaches are grown, except in some parts of the West where *S. exitiosa graefi* (Hy. Edw.), or the western peach tree borer, occurs.

The adult is a clearwing moth, steel blue with yellow or orange markings; both pairs of wings of the male are very largely clear, and there are several narrow yellow bands on the abdomen; the female's fore wings are covered with metallic blue scales, and there is a broad orange band on the abdomen. The female is about 1 inch in length, the male slightly smaller. The moths are day fliers and may easily be mistaken for wasps. Fully grown larvae may exceed a length of 1 inch and are white with brown heads (Fig. 419).

The insects winter as larvae of all sizes in their burrows at the bases of trees. In the spring they complete their growth and then spin tough silken cocoons covered with their sawdust borings and soil particles. These are situated about an inch below the soil surface in an upright position near the base of the tree (Fig. 420). Pupae may be found from early June to September, moths from late June to October; they are most prevalent in July, August, and early September, depending on the latitude. The brown

Fig. 419. The peach tree borer, *Sanninoidea exitiosa* (Say). (Slingerland.)

Fig. 420. (Left) young peach tree borer in base of small tree; (right) ring of paradichlorobenzene before covering with soil.

Fig. 421. Eggs of the peach tree borer, a natural group and a single egg. (Slingerland.)

eggs (Fig. 421) are usually laid on the tree trunks, sometimes on foliage of sprouts and even on other nearby objects. Incubation requires a little more than a week, and newly hatched larvae are present from midsummer to early fall. Young larvae make their way to the base of the tree, bore into and feed on the inner bark and cambium layer. Exudations of gum usually mixed with the borings of the larvae indicate the presence of the insect. There is only one generation each year.

Common parasites include the braconid, *Bracon sanninoideae* (Gahan); the bombyliid, *Villa lateralis* (Say), and the egg parasite, *Telenomus quaintancei* Girault. Predators include ants, chrysopid larvae, spiders, moles, mice, and skunks.

Older control methods consisted of removing the borers by hand in the fall or spring, fall treatment of the soil around each tree with paradichlorobenzene, and fall or spring treatment of the same area with ethylene dichloride emulsion. The latter treatments consists of levelling the soil surface around each tree, then circling the tree trunk with paradichlorobenzene crystals (Fig. 420), at a distance of 1.5 inches from the trunk, and covering them with soil compacted in a mound to retain the gas and enable it to penetrate into the burrows of the borers. Use 0.25 to 0.5 ounce per tree one to three years of age, 0.75 ounce for four- to five-year old trees, and 1 to 1.5 ounces for trees six years of age and older. If borers are working above the soil level, additional soil should be mounded around the tree up to the point of borer activity before the chemical is applied.

PDB is not effective when soil temperatures are below 60° F. Therefore treatments should be made about September 1 in Michigan. October 1 in southern Ohio, and November 1 in southern Georgia. Areas intermediate to these may adjust their treatment dates accordingly. Commercial emulsions of ethylene dichloride are available and should be applied in the same manner as indicated for PDB. Since the liquid readily volatilizes, treatment may be made at any time during the fall or spring. The direc-

tions of the manufacturer should be followed. Level off all mounds in the spring if this has not been done earlier.

Spraying the tree trunks to kill adults, eggs, and young larvae before they enter the bark, has become the popular method of control. Sprays may be applied during one or more regular spray periods, thus requiring much less labor than hand-worming or the fumigation method. The most common materials are DDT, parathion, guthion, EPN, and endosulfan. In bearing orchards where 2 pounds of 50% DDT wettable powder in 100 gallons of water are applied in the third and fourth cover sprays to control oriental fruit moth, and where the tree trunks are also carefully sprayed, only one more treatment is needed for borer control. It should be made about three weeks after the fourth cover spray. The usual dosage for this spray is 4 pounds of 50% DDT wettable powder in 100 gallons of water. Parathion is used at the rate of 2 pounds of 15% wettable powder in 100 gallons of water. The timing of the sprays varies from one area to another because of variation in adult emergence dates, but in the latitude of southern Ohio the first application should be made about July 1, with the second and third following at three- to four-week intervals. In Georgia under heavy infestation, four applications at about four-week intervals starting around August 1 may be necessary. Wettable powder dosages for the other insecticides are the following: 2 pounds 25% EPN, $1\frac{1}{2}$ pounds 50% endosulfan, 1 pound 50% guthion, in 100 gallons of water. If these fit into a regular peach spray program, they may replace other recommended materials. Some of them are quite appropriate chemicals for treating nursery stock and young nonbearing orchards, or as special sprays for tree trunks only. Backyard orchardists should prepare a slurry of the chemical using the wettable powder in water. This is applied to the tree trunk with a paint brush. One application of the proper chemical should last the entire summer. Preplant treatment for seedlings also has merit.

References: *N.J. Agr. Exp. Sta. Bul.* 391, 1923; *J. Econ. Ent.*, 42:343–345, 1949; 45:611–615, 1952; 46:704–705, 1953; 47:359–360, 1954; 52:804–806, 1959; 56:463–465, 1963; *Conn. Agr. Exp. Sta. Bul.* 575, 1953; *U.S.D.A. Tech. Bul.* 854, 1943; *Agr. Inf. Bul.* 272, 1963.

LESSER PEACH TREE BORER

Synanthedon pictipes (G. and R.), Family Aegeriidae

The lesser peach tree borer is similar in many respects to the larger species but has some distinct differences in appearance and habits. Both males and females of the lesser borer have front wings devoid of scales, the color is metallic blue-black marked with yellow, and the female lacks the orange band (Fig. 422). Important over much of its range as a pest of peach, plum, and cherry, the lesser borer shows a preference for peach. A little less likely to be a primary pest, it tends to enter the wood through

Fig. 422. The lesser peach tree borer, *Synanthedon pictipes* (G. and R.). (U.S.D.A.)

areas of the trunk and limbs which have been injured by implements, cankers, low temperatures, or sunscald. It works usually in the upper part of the trunk and in the scaffold branches. When found at the base of the tree, it is often in wounds made by the peach tree borer.

Early in the spring the overwintering larvae change to pupae and begin emerging as adults, usually a month earlier than the peach tree borer. Along the trunks and limbs of the tree are deposited the brown eggs, which hatch into white larvae with brown heads. A second generation occurs in the South, but only one occurs in the latitude of the Dakotas.

Control has been accomplished by painting infested areas only with a mixture containing 2 pounds of paradichlorobenzene dissolved in 1 gallon of previously warmed miscible spray oil which is then diluted with 1 gallon of water. A mixture containing the same amount of PDB in 1 gallon of crude cottonseed oil has been tried with success. Application can be made in the fall or in the spring before April 15. Commercial control can be obtained by three or four applications of parathion, EPN, guthion, endosulfan, or malathion sprays to the tree trunks and larger branches at three- or four-week intervals, beginning when the first adults emerge, late May for the north central states. Where some of these same insecticides are applied for the control of other peach pests, special sprays for the lesser peach tree borer may not be necessary. Malathion is recommended for the amateur grower only.

References: *Ohio Agr. Exp. Sta. Bul.* 307, 1917; *Res. Bul.* 768, 1956; *J. Econ. Ent.*, 45:611–615, 1952; *U.S.D.A. Agr. Inf. Bul.* 272, 1963.

PEACH BARK BEETLE

Phloeotribus liminaris (Harris), Family Scolytidae

The peach bark beetle is a native insect found generally east of the Mississippi River from Tennessee and Maryland northward. It attacks mainly peach, cherry, and plum, occasionally mountain ash, and resembles

the shot-hole borer (Fig. 364) in both larval and adult stages (Fig. 423). A comparison of the figures shows that the shot-hole borer has the abdomen very sharply slanting from the tips of the elytra to near the base of the hind legs, whereas in the peach bark beetle there is no such declivity.

The peach bark beetle winters under the bark of the tree in the adult stage, and emerges and lays its eggs early the following summer. Two generations are produced each year. The presence of this species may be determined by the parent egg gallery, which almost always runs across the grain and is forked at one end, whereas the larval galleries run with the grain. Sap flow from the plant parts under attack causes gummy exudates on the surface.

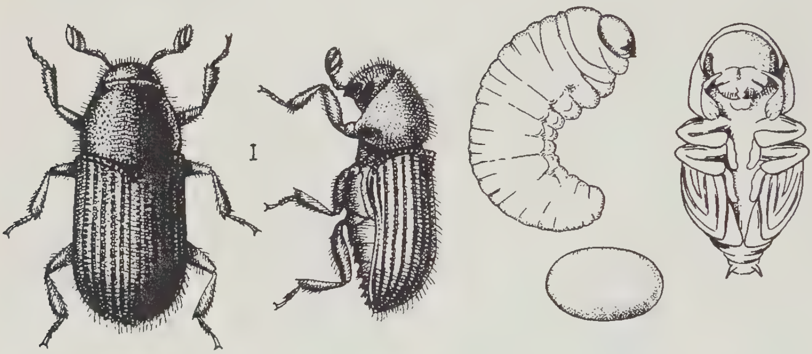


Fig. 423. Life stages of the peach bark beetle, *Phloeotribus liminaris* (Harris). (U.S.D.A.)

Fig. 424. Peach twigs injured by the tarnished plant bug. (Slingerland.)

Control of this bark beetle is based on the same general principles outlined for the shot-hole borer (p. 416).

TARNISHED PLANT BUG

Lygus lineolaris (P. de B.), Family Miridae

This bug commonly attacks apple, pear, peach, plum, and quince both in the nursery and in commercial orchards. Blossoms, buds, and developing fruits are most often attacked; peach trees also suffer much twig injury (Fig. 424). Heavy feeding may cause fruits to become deformed. Peaches are especially susceptible, and the injury is sometimes described as "catfacing." Sunken areas more or less conical in shape with corky tissue at the bottom are indicative of early plant bug damage to fruits. Leguminous cover crops or adjacent plantings of the same favor high bug populations in the orchard.

Related species are *Lygus hesperus* Knight and *L. elisus* V. D. These occur in the western and southwestern states.

Adults are scarcely $\frac{1}{4}$ inch in length. They are brown, tan, or green, always with darker markings (Fig. 425). Most specimens show the rusty appearance that is the basis for the common name. Nymphs are shades of green or yellow.

In its southern range, breeding is continuous; northward, the adults hibernate. Activity begins in the spring, and injury to blossoms and buds

Fig. 425. The tarnished plant bug, *Lygus lineolaris* (P. de B.). (U.S.D.A.)

is caused by these overwintering bugs. Eggs are laid in the stems, petioles, and midribs of the hosts. Hatching occurs in approximately seven days, and the nymphs molt five times before becoming adults, requiring almost thirty days. There are three to five or more generations annually, depending on the latitude.

Clean culture around gardens, nurseries, and orchards, especially the elimination of a rank growth of weeds and leguminous plants, will do much to prevent injury. Spraying orchard trees with wettable powder formulations of DDT, dieldrin, EPN, guthion, or parathion just before bloom and at petal-fall will control plant bugs. Two applications may be needed where heavy infestations prevail. Where feasible, treating infested areas adjacent to orchards early in the spring helps in reducing plant bug damage.

References: *Mo. Agr. Exp. Sta. Res. Bul.* 29, 1918; *J. Econ. Ent.*, 42:335–338, 1949; *U.S.D.A. Agr. Inf. Bul.* 272, 1963; *Ohio Agr. Exp. Sta. Res. Bul.* 768, 1956.

CHERRY FRUIT FLIES

Order Diptera, Family Tephritidae

Two native species of fruit flies are important pests of wild and cultivated cherries in the larval stage. They are the cherry fruit fly, *Rhagoletis cingulata* (Loew), and the black cherry fruit fly, *R. fausta* (Osten Sacken) (Figs. 426 and 427). Both are generally distributed in the cherry-growing areas of southern Canada and northern United States, but *R. fausta* is found farther north and west. The quality and market value of the crop are greatly reduced by the maggots feeding in the flesh near the

Fig. 426. The cherry fruit fly, *Rhagoletis cingulata* (Loew): *a*, fly; *b*, maggot; *c*, anterior spiracles of maggot; *d*, puparium; *e*, posterior spiracular plates of puparium. (U.S.D.A.)

Fig. 427. The black cherry fruit fly, *Rhagoletis fausta* (Osten Sacken). (Eichmann, Mont. Agr. Exp. Sta.)

Fig. 428. A cherry, enlarged to show the maggot of the cherry fruit fly and character of its damage. The small figures above show the maggot and parent fly, natural size. (Slingerland.)

seed, often causing malformed fruits (Fig. 428). The typical species attacks both sweet and sour cherries; the dark form shows preference for the sour varieties.

Adults of both species are a little more than half the size of the house fly and have wings marked with dark bands. The body color is dark with yellow markings, often distinctly darker in *R. fausta*, which usually has more prominent dark bands on the wings. The larvae are white, legless tapered maggots, nearly $\frac{1}{4}$ inch long when fully grown.

Life histories and habits are also very similar for both species. Winter is passed as puparia in the soil. Adults emerge in late spring and lay their eggs in the fruits, one fly being capable of producing over 300. Larval development is completed within the cherries, after which they drop to the ground and change to puparia. Many larvae are likely to be in the fruits of early varieties at harvest time and may be distributed in shipment. Only one generation develops each season.

Both destruction of infested fruits and cultivation to destroy the puparia have been recommended as control practices. Insecticides are necessary for the production of a clean crop. Those commonly recommended are 3 pounds of lead arsenate, 3 pounds of derris or cubé powder (containing 4% rotenone), 1 pound of methoxychlor or Perthane, 0.5 pound of malathion or diazinon, 0.15 pound of parathion, 0.25 pound guthion, in 100 gallons of water. Combinations of methoxychlor plus parathion or

diazinon have also been recommended. Proper timing is essential for successful control since the adults must be killed just as they are emerging and before they lay their eggs. Usually two to four applications at seven- to fourteen-day intervals are required, beginning when the first flies are trapped. Three applications at seven- to ten-day intervals are suggested for derris or cubé sprays. All fruits should be washed at harvest. Special attention should be given to the safety residue period from the last application and harvest date for the particular insecticide employed.

References: *N.Y. Agr. Exp. Sta. Bul.* 325, 1912; *Mich. Agr. Exp. Sta. Bul.* 131, 1930; *Mont. Agr. Exp. Sta. Bul.* 313, 1936; *U.S.D.A. Cir.* 270, 1950; *Agr. Handbook* 290, 1965.

MISCELLANEOUS INSECTS ATTACKING STONE FRUITS

Cherry Fruitworm, *Grapholitha packardi* Zeller, is the larva of a very small mottled gray moth related to the oriental fruit moth. It has become quite injurious to cherries from Colorado northward and westward to British Columbia and Vancouver Island. It has been reported as being present in New Jersey, Iowa and Wisconsin. Its native host seems to have been wild cherry but it is known to attack blueberry.

Larvae hibernate in galleries in the bark or twigs and pupate in the spring. Moths begin emerging in early June and lay tiny, flattened eggs on the fruits. A week later hatching begins, and the white larvae with black heads bore into the green cherries and feed about the pit. In almost three weeks the larvae mature to a length of $\frac{3}{8}$ inch. There is only one complete generation each year, but a partial second may develop in some areas.

To prevent damaged fruits apply parathion or methoxychlor. Wettable powders containing 2 pounds of either 15% parathion or 50% methoxychlor in 100 gallons of water are the required dosages. Make two or three applications ten to fourteen days apart, starting when the moths appear in early June.

Reference: *J. Econ. Ent.*, 45:800–805, 1952.

Cherry Curculio, *Tachypterellus consors cerasi* List, is a relative of the apple curculio. It feeds on native wild cherry but has also adopted some of the cultivated varieties and at times is a destructive pest. The adult snout beetles hibernate during the winter, feed on foliage, blossoms, and young fruit in the spring, then lay their eggs in the fruit where the white legless larvae develop, feeding on the flesh and in the pit of the cherry. Pupation takes place within the pit, and adults emerge and feed on some varieties of cherries as they are ripening. After a short period of activity the adults go into hibernation. All life stages are illustrated in Fig. 429.

Much natural control occurs in Colorado where the insect has been troublesome. Parasitism as high as 75% has been recorded.

Fig. 429. The cherry curculio, *Tachypterellus consors cerasi* List. (Palmer, from List, Colo. Agr. Exp. Sta.)

A blossom fall spray, followed by two other treatments at intervals of one to two weeks, with the recommended dosages made for plum curculio, is the suggested control program.

Reference: *Colo. Agr. Exp. Sta. Bul.* 385, 1932.

Cherry Leaf Beetle, *Pyrrhalta cavicollis* (LeC.), is a small red chrysomelid, less than $\frac{1}{4}$ inch in length. Its larvae are slaty gray with yellow markings. The form of both stages is illustrated in Fig. 430. This beetle develops to maturity only on wild cherry, *Prunus pennsylvanicus,* but when the foliage of this host is destroyed adults migrate to cultivated varieties and cause serious damage. Peach, plum, and occasionally apple are also attacked.

Adults emerge from hibernation in late May and begin laying eggs by mid-June. Hatching occurs in two or more weeks, and the larvae feed

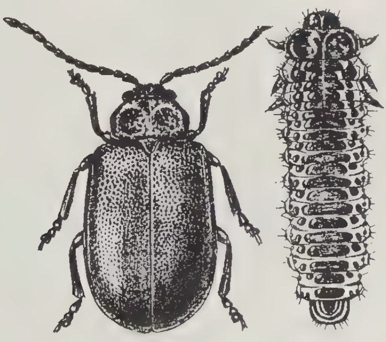


Fig. 430. Adult and larva of the cherry leaf beetle, *Pyrrhalta cavicollis* (LeC.). (U.S.D.A.)

an average of twelve days, then enter the soil, and form cells where pupation takes place. The average period from egg deposition to adult emergence is forty-three days. Only one generation occurs each year.

Orchards that receive a regular spray program for curculio and cherry maggot have not been troubled with this insect.

Reference: *N.Y. Agr. Exp. Sta. Bul.* 444, 1917.

Cherry Casebearer, *Coleophora pruniella* Clemens, has caused some damage in commercial cherry orchards in Michigan and Wisconsin. The usual food plant is wild cherry but cultivated varieties are also attacked when high populations develop. Injury results when tiny larvae inside silken cases feed on the buds, blossoms, and foliage. When fully grown they attach their cases or cocoons to twigs and pupate (Fig. 431). Small buff moths emerge in June and lay eggs. These hatch into larvae that feed for a short time and then become inactive, eventually hibernating. The insecticides normally applied for the major insects attacking cherries evidently control this pest since no reports of damage have been made.

Cherry Fruit Sawfly, *Hoplocampa cookei* (Clarke), is a Pacific Coast pest of cherries and plums, sometimes peaches and apricots. The black-bodied adults with yellow appendages are only $\frac{1}{8}$ inch in length. Larvae are yellow-white and about $\frac{1}{4}$ inch in length when fully grown. Eggs are laid in the blossoms, and the young larvae enter the fruits and feed on the developing seeds. Some fruits wither, others drop. In less than a month development is completed and the larvae leave the fruits and enter the soil where pupation occurs. Adult emergence takes place the following spring; there is but one generation per year. Early sprays of DDT or parathion prevent injury, the applications being made before the blossoms open to kill the newly emerging adults before they lay eggs.

References: *Calif. Cir.* 227, 1921; *Leaflet* 72, 1966.

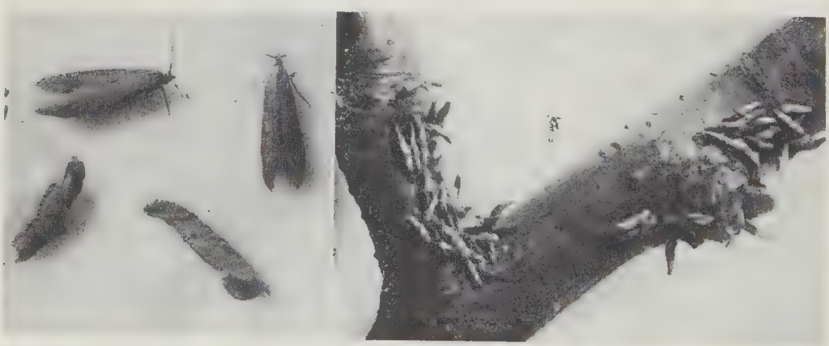


Fig. 431. The cherry casebearer, *Coleophora pruniella* Clemens; adults and cocoons. (Mich. Agr. Exp. Sta.)

Cherry and Hawthorn Leaf Miner, *Profenusa canadensis* (Marlatt), is an occasional pest of Morello cherries and often quite damaging to ornamental hawthorn in the north central and New England states. Adults are black-bodied sawflies, nearly $\frac{3}{16}$ inch in length. The dorsal side of the prothorax is black in the males and orange in the females. They emerge in late April and early May from pupae in the soil and lay their eggs in the leaves of the hosts. The nearly white maggot-like larvae devour the tissue between the upper and lower leaf epidermis (Fig. 432), pass through five instars during a period of almost a month, then drop to the ground, enter the soil and remain in an earthen cell until late winter when pupation begins. Only one generation occurs each year.

Spraying ornamental hawthorn with emulsions of dieldrin or lindane just as soon as the leaves are fully expanded will control this pest. Use 1 quart of 15% dieldrin or 25% lindane in 100 gallons of water. One thorough application should be sufficient. On Morello cherries the regular sprays of guthion or parathion applied at petal-fall and ten to twelve days later should solve the problem.

References: *N.Y. Agr. Exp. Sta. Bul.* 411, 1915; *J. Agr. Res.*, 5:519–529, 1915; *J. Econ. Ent.*, 43:694–696, 1950; 52:1218–1219, 1959.

Plum Web-Spinning Sawfly, *Neurotoma inconspicua* (Norton), occurs throughout the northeastern states, westward into the Dakotas and in Manitoba, Canada. The larvae feed in colonies on the webbed foliage of plums and sand cherries. Adult sawflies appear in early summer and lay eggs. On hatching the larvae feed and mature by midsummer, when they enter the soil and remain inactive until spring, at which time they pupate. The adults have black bodies and red legs; the larvae are gray-

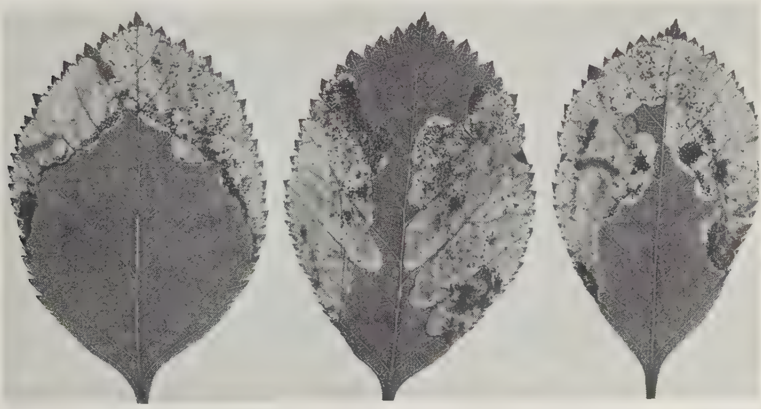


Fig. 432. The cherry and hawthorn leaf miner, *Profenusa canadensis* (Marlatt). Larvae can be seen in the mines.

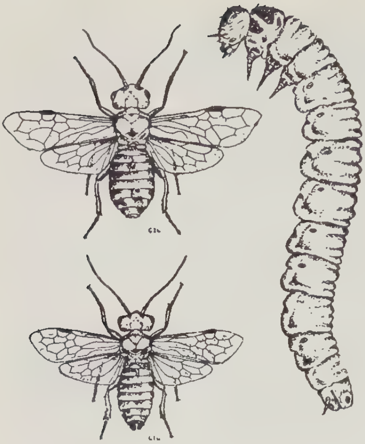


Fig. 433. The plum web-spinning sawfly, *Neurotoma inconspicua* (Norton). (Severin, S.D. Agr. Exp. Sta.)

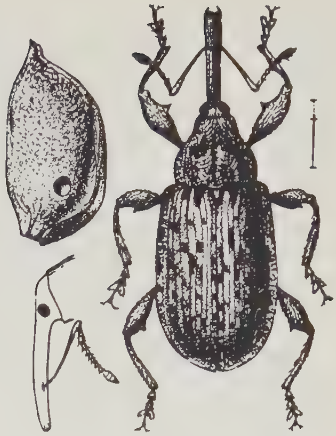


Fig. 434. The plum gouger, *Anthonomus scutellaris* LeConte. (U.S.D.A.)

green dorsally and yellow ventrally, and attain a length of $\frac{3}{4}$ inch when fully grown. Their prolegs are poorly developed (Fig. 433). Many natural enemies normally keep them checked. If control is necessary, apply lead arsenate or DDT when larval feeding is just beginning.

Plum Gouger, *Anthonomus scutellaris* LeConte, is a snout beetle resembling the plum curculio, but scarcely as large and of more slender form, and entirely lacking the characteristic humps on the back (Fig. 434). The gouger attacks plums and cherries, occasionally peaches and apples. It is widely distributed but most reports of damage have come from the Dakotas and other states in the same general region. The life history is similar to that of the plum curculio; however, adults emerge from hibernation earlier and the larvae pupate not in the soil but in the developing seed of the fruit attacked, into which they bore when fully grown. When these insects are injurious, the first spray application should be made before the trees bloom; other sprays should follow, employing the same materials and timing as those recommended for the plum curculio.

Green Peach Aphid, *Myzus persicae* (Sulzer), is also known as the spinach aphid. It is rather slender in form, light green or yellow, with indefinite darker stripes on the abdomen (Fig. 435). Its fruit tree hosts include all the stone fruits. The black, shiny, winter eggs are placed on these plants and, about the time peach trees bloom, hatching occurs, the nymphs developing into wingless females which give birth to succeeding

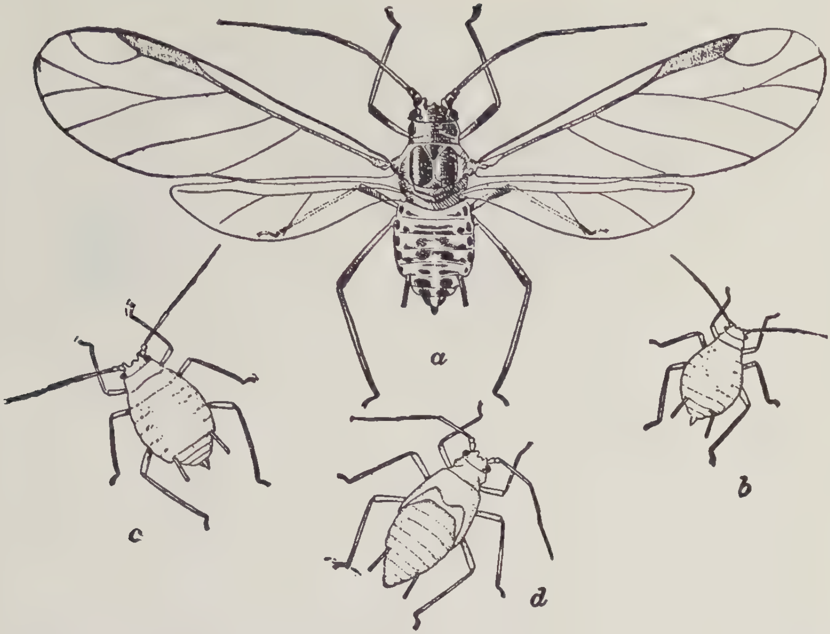


Fig. 435. The green peach aphid, *Myzus persicae* (Sulzer); also known as the spinach aphid. A pest of several vegetable crops. *a,* winged adult; *b,* young nymph; *c,* older nymph; *d,* last stage of nymph; all greatly enlarged. (U.S.D.A.)

generations. After two or three generations winged forms are produced that migrate to the various herbaceous alternate hosts, pepper, potato, tobacco, spinach, lettuce, and other vegetables being quite important in this respect. Here repeated generations are produced, and with the approach of cold weather winged migrants again return to peach and other stone fruits and give birth to the sexual forms that eventually mate and lay the overwintering eggs. In the South all generations may be parthenogenetic. Damage to the blossoms, leaves, and fruits of peach trees is rarely serious from these sap-feeding insects, but at times tobacco and garden crops are severely injured. Insects that reduce populations of this aphid are lady beetles, lacewing larvae, syrphid fly larvae, *Aphidius testaceipes* (Cresson) and *A. matricariae* Hal. This aphid is a vector of the virus causing maize dwarf mosaic of corn.

When the aphids appear, apply sprays of demeton, endosulfan, guthion, malathion, nicotine sulfate, parathion, diazinon, mevinphos, or TEPP.

References: *Calif. Agr.* 17:10–11, 1963; *U.S.D.A. Agr. Handbook* 290, 1965.

Black Peach Aphid, *Brachycaudus persicaecola* (Boisduval), overwinters as black wingless forms feeding on the root sap of peach and sometimes

Fig. 436. The black peach aphid, *Brachycaudus persicaecola* (Boisduval). (Quaintance.)

plum. The life cycle of this aphid has not been thoroughly investigated, but it is known that some of the root forms migrate to new growth above ground in the spring and increase in numbers rapidly. Winged forms eventually develop that fly to other trees and possibly other hosts where new infestations are established (Fig. 436). All aerial forms usually disappear by midsummer. It is not known whether sexual forms are ever produced. Young trees may be seriously injured by the forms on the roots, but older trees suffer little root injury and rarely much from the leaf-infesting forms. The root forms are attended by ants, but how important the ants are in maintaining the population has not been learned. If ants should be important, treating the soil under the trees with chlordane, aldrin, heptachlor, or dieldrin might help to eliminate an infestation. The usual control measures are spraying with one of the insecticides suggested for green peach aphid.

a *b* *c*

Fig. 437. The mealy plum aphid: *a*, young nymph; *b*, last stage of nymph of winged form; *c*, winged female; all much enlarged. (Lowe.)

Mealy Plum Aphid, *Hyalopterus pruni* (Geoffroy), another importation from Europe, is rather light green but usually appears gray because of the blue-white powdery substance that covers the body (Fig. 437). It winters in the egg stage on plum and produces a few early generations in the spring on this host. In early summer winged forms develop and migrate to grasses, on which they feed and reproduce until fall; winged migrants then return to plum and give birth to the sexual forms that complete their development, mate, and deposit the overwinterings eggs. All generations are parthenogenetic ovoviviparous females, except the sexual forms that develop in the fall and lay eggs. Injury results from removal of plant sap, causing stunting of growth, and smudging of fruits and foliage with honeydew. This aphid has been especially injurious in California where prunes and apricots are also attacked.

When aphid populations indicate the need for control measures apply a spray containing parathion, demeton, diazinon, malathion, trithion, or nicotine sulfate. For killing the eggs, dormant sprays of oil emulsions alone or in combination with dinitro compounds are recommended.

References: *Calif. Agr. Exp. Sta. Bul.* 606, 1937; *Leaflet* 77, 1966.

Rusty Plum Aphid, *Hysteroneura setariae* (Thomas), has also been called the southern plum aphid. Although it occurs in the North it is distinctly a southern pest. It attacks plum, cherry, occasionally peach and sometimes grain sorghums. It also transmits sugarcane mosaic virus. It is rusty in appearance, with white markings at the base of the antennae, the tibiae, and the tip of the abdomen, thus being readily distinguished from other aphids on the same hosts (Fig. 438). The most important injury is done by those aphids which work in the blossoms and prevent the setting of fruits, although foliage injury may also be severe. The life history is similar to that of the mealy plum aphid. Eggs pass the winter on the woody hosts, and a few wingless generations of parthenogenetic, ovoviviparous females are produced in the spring, followed by winged forms migrating to grasses, then a later migrating generation returning in late fall to the tree hosts, upon which the egg-laying sexual forms are produced. The same sprays recommended for mealy plum aphid control this species. Controlling ants in sugarcane fields greatly reduces populations of this aphid on sugarcane.

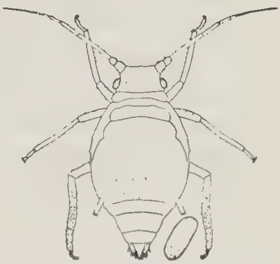


Fig. 438. The rusty plum aphid, *Hysteroneura setariae* (Thomas). (Sanborn.)

Reference: *J. Econ. Ent.*, 54:204, 1961.

Fig. 439. The black cherry aphid, *Myzus cerasi* (F.); 1, apterous female; 2, winged female. (Gillette and Taylor, Colo. Agr. Exp. Sta.)

Black Cherry Aphid, *Myzus cerasi* (F.), is a European species that has become the most common member of the family attacking cherry in most parts of this country. Its shiny black coloration is sufficient for identification, as no similar insect attacks the same hosts (Fig. 439). Sweet cherries are the favored host; other varieties of cherries and stone fruits are rarely damaged. The winter eggs, which are tucked in among the buds, hatch about the time the buds are bursting. The nymphs suck plant sap and develop rapidly on the new growth, causing curling and distortion of the leaves. There are several generations of wingless, parthenogenetic, ovoviviparous females. Winged adults develop in midsummer and migrate to water cress, peppergrass, and other plants of the mustard family, and give birth to succeeding generations. Winged individuals again develop in late fall that return to cherry and produce the wingless sexual forms that lay the overwintering eggs.

Commonly recommended insecticides applied at the green tip stage, or in the summer as needed, are diazinon, endosulfan, malathion, parathion, or TEPP. Recommended ovicides are dormant oil sprays alone or in combination with dinitro compounds.

References: *Calif. Agr. Exp. Sta. Leaflet* 72, 1966; *U.S.D.A. Agr. Handbook* 290, 1965.

19

Insects Injurious to Grapes

GRAPE BERRY MOTH

Paralobesia viteana (Clemens), Family Olethreutidae

The berry moth is generally distributed east of the Rocky Mountains. It is much more troublesome in some sections than in others, being especially destructive in the large grape-growing areas east of the Mississippi River and north of the Ohio River. It is the only common insect which does extensive damage to grape berries; the grape curculio, which also feeds inside the fruit, is much less abundant and rarely a serious pest.

The brown moth, with an irregular pattern of darker and lighter markings, has a wingspread of slightly more than $\frac{1}{2}$ inch. The larvae are green or gray-green, slightly hairy, and nearly $\frac{1}{4}$ inch long (Fig. 440).

Moths begin to emerge from overwintering pupae when grape foliage is well unfolded, usually about the first of June, continuing over a period of several weeks. They lay their tiny scale-like eggs on the grape stems, blossom clusters, or berries. Newly hatched larvae feed on the blossoms and small berries, often leaving a silken thread wherever they crawl, resulting in webbed clusters. One larva may injure or destroy several grape berries. In three or four weeks they become fully grown and each makes a somewhat semicircular cut in the leaf, folds over this portion and ties it with silk, thus forming a cocoon inside which pupation takes place. Second-generation moths begin emerging ten to fourteen days later and once more lay their eggs, this time on the berries. Peak adult emergence usually occurs about mid-August. Larvae of this generation eat their way into the berries and feed on the pulp and seeds. There are normally two generations each year but a partial third may develop in more southern areas. Full-grown larvae of the last generation pupate inside the cocoons made in the leaves. Many cocoons become detached and fall to the ground; others remain and drop with the leaves in the autumn.

The only biological controlling factor which has been found to be of appreciable value is the egg parasite, *Trichogramma minutum* Riley.

Where feasible, cultural practices aid greatly in reducing the overwinter-

Fig. 440. The grape berry moth; *Paralobesia viteana* (Clemens); adults, larvae, infested grapes, and cocoons in leaf. (Slingerland.)

ing population. Success of these practices depend on plowing or cultivating so as to bury the cocoons containing overwintering pupae, thereby preventing emergence of adults. A popular method is to throw the soil from the row centers into a low ridge under the grape trellis with a grape hoe, disk, or plow. Do this operation thirty to forty-five days before harvest. Make the ridge flat and wide, letting it remain during the winter. Make the row centers almost level and seed them to a winter cover crop. In the spring, at least fifteen days before grape bloom, pull the soil ridge with the cocoons on its surface from under the trellis into the row centers with a mechanical grape hoe. With a hand hoe pull out any islands of soil left around the posts and grapevines into the row centers. Then disk or plow the row centers to bury the cocoons. Use a straight disk followed by a cultipacker. Rains after this operation help to seal in the cocoons. This practice has reduced berry moth populations to a point where shortened spray schedules can be used.

It is impossible to make a grape spray schedule fit all situations and localities. In most vineyards with a berry moth problem, at least three and more often four spray applications are advisable. Each grower should study his conditions and apply only necessary sprays. The first is made at postbloom, the second seven to ten days later, the third about the first of August, and the fourth in mid-August. Commonly recommended chemicals are DDT, methoxychlor, carbaryl, diazinon, guthion, and parathion. Combination sprays of parathion plus DDT, methoxychlor, or carbaryl have been used with success. Should spraying after mid-August be necessary to control berry moth only carbaryl, guthion, or diazinon are recommended because of the danger of toxic residues at harvest. A hooded spray boom is necessary for effective grape insect control.

References: *Del. Agr. Exp. Sta. Bul.* 198, 1936; *J. Econ. Ent.*, 42:507–514, 1949; 43:76–81, 152–157, 1950; 45:101–104, 1952; 46:77–84, 1953; *U.S.D.A. Farmers' Bul.* 1893, 1961; *Agr. Inf. Bul.* 252, 1962; *Agr. Handbook* 290, 1965.

GRAPE LEAFHOPPERS

Order Homoptera, Family Cicadellidae

Throughout the United States and Canada where grapes are grown, various species of leafhoppers will almost invariably be found sucking the juices from the lower surfaces of the leaves. This causes the foliage to become blotched with tiny white spots and under heavy infestation the leaves will turn yellow or brown, many falling from the vine. Since their feeding seriously interferes with the normal photosynthetic processes of the plant, the quantity and quality of the fruit are greatly reduced. Other hosts are Virginia creeper, apple, plum, currant, gooseberry, raspberry, and dahlia.

Apparently the most common species of the eastern grape regions is *Erythroneura comes* (Say), followed by *E. tricincta* Fitch (Fig. 441). Other species of importance in some areas are *E. ziczac* Walsh, *E. vitifex* Fitch, *E. vulnerata* Fitch, *E. vitis* Harris, and *E. elegantula* (Osborn). All species are scarcely more than $\frac{1}{8}$ inch in length, pale yellow, with red, yellow, or black markings on the front wings.

There seems to be little important difference in the biology of the various species except as it concerns their relative abundance in different areas on different hosts. They pass the winter as adults in protected places, usually under plant remnants on the ground. With the first warm days of spring the leafhoppers become active and feed to some extent on any green plant before grape foliage appears. Eggs are laid in the leaf tissue, hatching taking place in about two weeks. The pale, wingless nymphs feed on the lower surface of the leaves, molting five times before transforming to adults. This developmental period requires three to five weeks depending

Fig. 441. Grape leafhoppers: *a,* leaf showing appearance of injury; *b,* (right) *E. comes* (Say); (left) *E. tricincta* Fitch; *c,* a nymph. (U.S.D.A.)

on the temperature. There are two or three generations of these insects each season.

Some natural control of leafhoppers results from insect parasites and predators, and a fungus, *Entomophthora sphaerosperma* Fres.

Chemical control is accomplished by applying at the prebloom or postbloom periods, and at other times, if deemed necessary, one of the following pesticides: DDT, methoxychlor, demeton, malathion, carbaryl, endosulfan, Delnav, ethion, trithion, diazinon, naled, or guthion.

References: *Del. Agr. Exp. Sta. Bul.* 198, 1936; *U.S.D.A. Farmers' Bul.* 1893, 1961; *Can. Dept. Agr. Pub.* 35, 1946; *J. Econ. Ent.,* 40:195–198, 487–495, 1947; *Calif. Agr. Exp. Sta. Leaflet* 79, 1966.

GRAPE ROOTWORM

Fidia viticida Walsh, Family Chrysomelidae

Widely distributed from the Mississippi Valley eastward, this native insect is considered an important pest of grapes and related host species. It thrives in neglected vineyards. The larvae devour small roots and eat pits in the outer portion of larger roots, causing a general unthrifty condi-

tion of the plant and reduction in yield. When the larvae are abundant vines may be killed in three or more years. One of the best diagnostic characteristics of the presence of these insects is the chain-like feeding marks produced by the adult beetles (Fig. 442). They devour narrow strips of upper leaf epidermis, causing the lower surface to die. Beetles also feed on the surface of the green grape berries.

The adult beetle is hairy, chestnut-brown, and almost $\frac{1}{4}$ inch in length. The white larva is curved and hairy with a brown head. Adults make their appearance in vineyards about the end of the blooming period. After feeding on the foliage for a week or more they begin depositing clusters of creamy white elongated eggs on the canes, most often under loose bark. These hatch in a week or two, the larvae dropping to the ground and entering the soil where they feed until the approach of cold weather. Winter is passed in the larval stage in the soil at depths varying from a few inches to nearly 2 feet. They resume feeding and complete their development the following spring, pupation occurring in earthen cells usually near the surface of the soil and not far from the base of the vine. Approximately two weeks are spent in the pupal stage. One generation may develop each year, but many larvae require a second year to complete their development. The life cycle is illustrated in Fig. 443.

A related species is the western grape rootworm, *Adoxus obscurus* (L.), which is well known in Europe and ranges in North America from Alaska through the Rocky Mountain states. The appearance, life cycle, and habits are similar to those of the eastern species, and control is accomplished in the same way.

Control measures are directed toward eliminating the adults soon after emergence and before they deposit their eggs. The most widely used

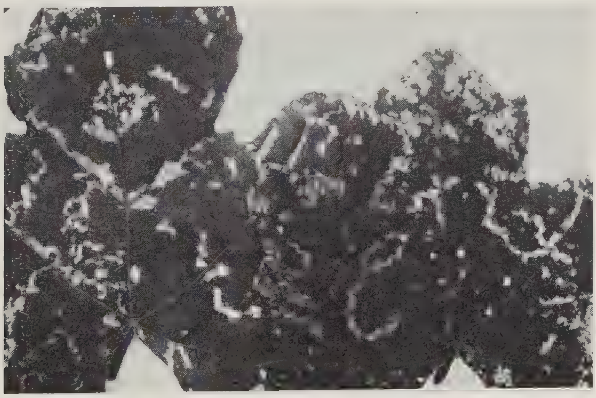


Fig. 442. Leaf damage by adults of the grape rootworm.

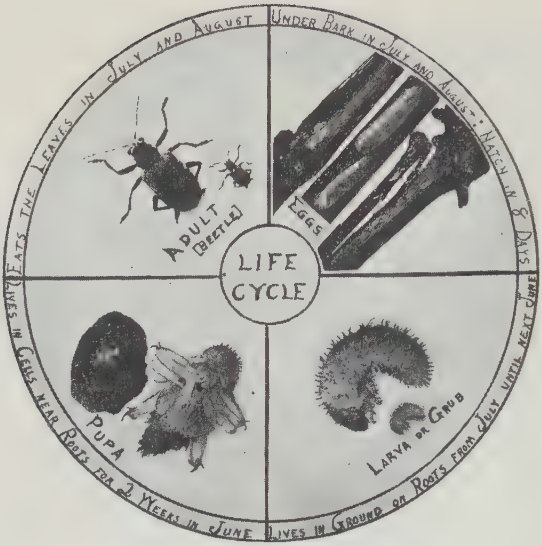


Fig. 443. The life cycle of the grape rootworm, *Fidia viticida* Walsh; enlarged and natural size. (Slingerland.)

insecticide is DDT, applied as a spray at the rate of 1.5 pounds of 50% wettable powder in 100 gallons of water. The first application should be made when the adult feeding marks appear, which is usually at petal-fall, and the second a week or ten days later. Grapes receiving a regular spray program will not be bothered by this pest.

References: *U.S.D.A. Farmers' Bul.* 1220, 1926; 1893, 1961; *Ark. Agr. Exp. Sta. Bul.* 426, 1942.

ROSE CHAFER

Macrodactylus subspinosus (Fabr.), Family Scarabaeidae

The name of this insect usually associates it with the rose; in discussions it is often included with the grape pests. Actually it is a general feeder and it is somewhat misleading to call it a pest of any one crop. Besides grape and rose, it also attacks many tree fruits, raspberry, blackberry, strawberry, peony, iris, dahlia, hollyhock, and other garden plants. The beetle is native to this country and occurs generally west to the Rocky Mountains. More abundant in areas having light sandy soil, the beetles feed on flowers, leaves, and fruits, and the larvae feed in the soil on roots of various grasses and weeds.

The larvae resemble small white grubs. They pass the winter deep in the soil and migrate upward in the spring, completing their development and

Fig. 444. The rose chafer, *Macrodactylus subspinosus* (Fabr.).

transforming to pupae in early May. Light tan long-legged beetles nearly $\frac{1}{2}$-inch in length begin emerging in late May and early June (Fig. 444). Some years they are extremely abundant and cause serious damage. Feeding, mating, and egg-laying occur into early July, the eggs being deposited singly a few inches below the surface of the soil. Hatching takes place in two or more weeks, and the grubs feed until cold weather, becoming nearly fully grown. Only one generation occurs each year.

On grape, petal-fall sprays of DDT or methoxychlor for berry moth kills rose chafers, but the dosage should be increased to 2 pounds of 50% wettable powder to 100 gallons of water. On other hosts this same dosage should be applied when spraying. For flowers and small garden crops dusts are desirable; they should contain 5% DDT or methoxychlor. On fruit crops, DDT must not be used later than forty days and methoxychlor fourteen days before harvest. Control measures against the larvae have not been practiced, but the same chlorinated insecticides recommended for white grubs and Japanese beetle grubs are effective.

GRAPE FLEA BEETLE

Altica chalybea Illiger, FAMILY CHRYSOMELIDAE

This flea beetle is a native species occurring generally throughout the Mississippi Valley and eastward. In addition to cultivated and wild grapes,

Fig. 445. Injury by the grape flea beetle. (Pettit.)

Fig. 446. Adult grape flea beetle. (U.S.D.A.)

it is reported as feeding on Virginia creeper, plum, apple, pear, quince, beech, and elm. Damage is caused by the adults eating the buds and unfolding leaves of grape, and the larvae skeletonizing the foliage in a manner resembling adult rootworm feeding (Fig. 445).

Adults of this robust, metallic, blue-green beetle, almost $\frac{1}{5}$ inch in length (Fig. 446), emerge from hibernation and soon afterward deposit their light yellow eggs largely in cracks in the bark, at the base of buds, between bud scales, or on the leaves (Fig. 447). These eggs hatch in a few days, and the brown larvae, marked with black spots, feed for a three- to four-week period, then drop to the ground and pupate in the soil, emerging as adults a week or two later. The new adults feed the remainder of the summer and then go into hibernation in the fall, only one generation developing each season.

A related species is *Altica woodsi* Isely, which is about one-half as large, with metallic blue-purple adults and yellow larvae. Adults emerge from hibernation after the foliage is already expanded, and the other life stages occur correspondingly later. Larval feeding is confined largely to the leaves on which the eggs are laid. Otherwise, the life cycle and habits are similar to those of *A. chalybea.*

Growers following a spray schedule for controlling berry moth and leafhoppers will not be troubled with grape flea beetle. The insect thrives best in neglected vineyards. Where it is necessary to treat for this insect only, apply a spray of 2 pounds of 50% DDT wettable powder, or 3 pounds of lead arsenate in 100 gallons of water. Make the first application when the damage is evident, and repeat ten days later if necessary.

Fig. 447. Eggs of the grape flea beetle, natural size at *a*, and enlarged at *b*. (Slingerland.)

GRAPE PHYLLOXERA

Phylloxera vitifoliae **(Fitch), FAMILY PHYLLOXERIDAE**

The phylloxera is an insect native to eastern United States. It is established in Europe where it has been one of the most important enemies of European grapes; it has also been carried to California where it attacks European varieties of grapes. It is of relatively little importance on the grapes native to eastern United States.

The biology of this insect is very complicated, and anyone interested in the details should consult the references cited. Both winged and wingless individuals develop, reproduction is sexual and parthenogenetic, both oviparous and ovoviviparous females occurring. One form lives on the foliage, causing numerous knots or gall-like growths to develop (Fig. 448). This form is most abundant in eastern United States and is found primarily on wild grape species. Other forms are found on the roots (Fig. 449) where the most serious damage is done, galls being formed and the nutritional processes so seriously affected by these piercing-sucking insects that the vines are stunted, rendered unproductive, or die. This form is not common in the eastern states; it is the only important one in the Pacific Coast states.

Growers of American varieties of grapes, with a few exceptions, will not find phylloxera of sufficient importance as a pest to require consideration. Those planting European varieties should select vines grafted on resistant rootstocks of eastern United States. This practically eliminates any

Fig. 448. Grape phylloxera galls on leaf. (Ohio Agr. Exp. Sta.)

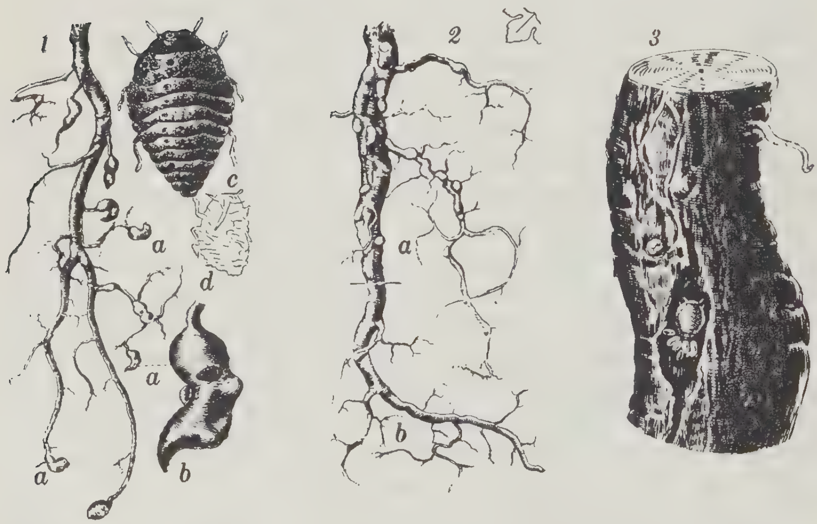


Fig. 449. The grape phylloxera; 1, *a*, root galls or nodosities; *b*, same, enlarged; *c*, adult; *d*, molted exoskeleton of same; 2, *a*, infested portion of small root; *b*, normal root; 3, large root showing insects and eggs *in situ*. (U.S.D.A.)

injury by this insect. Other control measures, such as flooding the vineyard or soil fumigants, are little used now.

References: *U.S.D.A. Dept. Bul.* 903, 1921; *Tech. Bul.* 20, 1928; *Farmers' Bul.* 1220, 1926.

GRAPE ROOT BORER

Vitacea polistiformis (Harris), Family Aegeriidae

This native insect attacks wild and cultivated grapes and is found in the eastern and central states as well as in the Pacific Northwest. It is seldom abundant in any part of its range and the injuries resulting from it are rarely noticed and usually local in distribution. The larvae bore into the roots, often girdling them, which reduces or destroys the productivity of the vine. An unthrifty condition of the plant is often the first symptom of their presence.

The adult is a moth related to the peach tree borer. It is wasp-like in appearance, dark lustrous brown with orange bands on the abdomen, and an over-all length of about an inch. The white larvae with brown heads are an inch or more in length, and their form and the nature of their damage are illustrated in Fig. 450.

Eggs are laid in late summer on foliage and on canes of grape or other plants in the vineyard, a single moth laying as many as 500. These hatch in two weeks, the larvae burrowing into the soil and tunnelling the roots for almost two years, then leaving the roots and pupating in cocoons near

Fig. 450. The grape root borer, *Vitacea polistiformis* (Harris); larvae in roots and adults on foliage. (W. Va. Agr. Exp. Sta.)

the soil surface in June. About one month later the new adults emerge and fly about several days before egg-laying begins.

A high degree of egg parasitism by a proctotrupid wasp has been reported. Cultivation to destroy the pupae and extra fertilization are mechanical and cultural control methods. The usual spray program for the important grape insects evidently keeps the root borer controlled since reports of damage are not common.

References: *W.Va. Agr. Exp. Sta. Bul.* 110, 1907; *U.S.D.A. Farmers' Bul.* 1220, 1926; *Proc. N.C. Branch Ent. Soc. Amer.*, 18:86, 1963.

GRAPE MEALYBUG

Pseudococcus maritimus **(Ehrhorn), Family Pseudococcidae**

Widely distributed in the United States, the grape mealybug is a pest which has been recorded on a remarkably long list of hosts. Besides pears and grape vineyards, it has also become troublesome in nurseries and ornamental plantings, particularly on *Taxus*. Damage is caused by removal of plant sap by the nymphs and adults, and from the honeydew voided by them which spots the leaves and fruits and serves as a medium for development of sooty fungus.

Their appearance is typical of all mealybugs. Winter is passed in the first instar within the shelter of the white cottony ovisac produced by the female. In April and May they become active, migrate over the twigs, and soon begin feeding. The adult stage is reached by late June, and eggs are deposited inside the white cottony ovisac. Several days later newly hatched crawlers appear and begin feeding, many getting into the grape

Fig. 451. The grape mealybug, *Pseudococcus maritimus* (Ehrhorn). (U.S.D.A.)

clusters (Fig. 451). Adults again appear in late August, and egg-laying continues until cold weather, the hatched eggs forming the overwintering population. Eggs which fail to hatch before cold weather in the autumn are not viable the following spring.

Mealybug eggs are frequently attacked by a hemerobiid predator and an encyrtid parasite, which often keep the insect checked. All life stages are preyed upon by lady beetles.

The best insecticide for controlling grape mealybug is parathion applied as a spray. Use 2 pounds of 25% wettable powder to 100 gallons of water, and treat the last week of May or early in June, or in early August for the second generation. Malathion at 1 pound in 100 gallons of water is also a recommended chemical, especially for the amateur gardeners. In some regions $1\frac{1}{2}$ pounds of parathion in 100 gallons of water is needed for control. Mealybugs are often attended by ants which assist in their spread. Perhaps by treating the soil under ornamental plants like yew with chlordane, aldrin, dieldrin, or heptachlor, ants would be eliminated and mealybugs indirectly checked.

References: *J. Econ. Ent.*, 42:41–44, 1949; 45:340–341, 1952; 55:849–850, 1962; 57:1–3, 372–374, 1964; *U.S.D.A. Farmers' Bul.* 1893, 1961; *Calif. Leaflet* 79, 1966.

GRAPE CURCULIO

Craponius inaequalis (Say), Family Curculionidae

The grape curculio occasionally is found feeding on grape berries, and its damage may be mistaken for that of the berry moth. It occurs from New England to Florida and west to the Mississippi Valley. The adult is a snout beetle, slightly more than $\frac{1}{10}$ inch in length and of a black shade (Fig. 452). They winter in sheltered situations and become active about the

Fig. 452. The grape curculio, *Craponius inaequalis* (Say): *a*, beetle; *b*, head of same from side; *d*, larva from above; *e*, same from below; *f*, pupa. (U.S.D.A.)

time that Concord grapes bloom. They spend almost two weeks feeding before egg-laying begins. Their feeding marks are on the upper surface of the leaves and appear as short, somewhat curved lines, usually in groups. Eggs are inserted into cavities formed by the mouthparts under the skin of the grape berries. The larvae develop inside the berries, feeding on the flesh and seeds. The legless condition of the white larvae distinguishes them from the caterpillars of berry moths. In three weeks the larvae are fully grown, after which they drop to the ground and pupate. New adults emerge a few weeks later, feed on grape foliage the rest of the summer, and go into hibernation with the approach of cold weather. The sprays applied for grape berry moth and leafhoppers control this insect.

GRAPE SCALE

Aspidiotus uvae **Comstock, Family Diaspididae**

Grape scale is widely distributed in North America. It is an armored species similar to San Jose scale in size and biology but differing in coloration. Many grape scales are almost white, giving badly infested canes a speckled appearance (Fig. 453). Besides cultivated and wild grape species

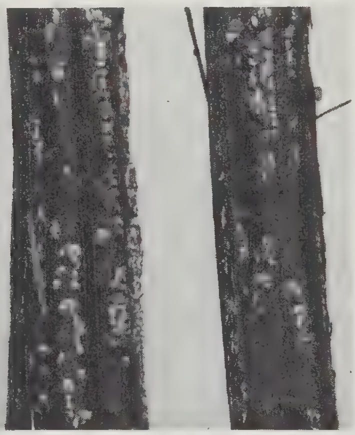


Fig. 453. The grape scale, *Aspidiotus uvae* Comstock.

it also attacks Virginia creeper, hickory, sycamore, and perhaps other hosts. Although usually not a serious pest, sometimes destructive populations are found, and chemical control measures are necessary. In that event apply 3% oil emulsion in the dormant period. During the growing season parathion or malathion sprays should also help eliminate an infestation.

GRAPE CANE GALL MAKER

Ampeloglypter sesostris (LeC.), Family Curculionidae

This small red-brown snout beetle, $\frac{1}{8}$ inch in length, causes gall-like swellings to form in grape canes in the region where the female deposits her eggs. With her chewing mouthparts the female punctures a grape shoot, usually just above one of the lower joints; in this puncture an egg is placed, and additional punctures are made above the first in which no eggs are deposited. On hatching the larva feeds in the pith, becoming mature, pupating, and emerging as an adult by late summer. The beetles hibernate and lay their eggs the following spring and early summer. The only control measure likely to be necessary is the destruction of infested canes as soon as the swellings have developed enough to indicate the presence of the insect. Vineyards following a regular spray program are not troubled by this insect.

References: *W.Va. Agr. Exp. Sta. Bul.* 119, 1909.

GRAPE CANE GIRDLER

Ampeloglypter ater LeC., Family Curculionidae

Like its congener, the grape cane girdler is a minor pest of grape. The two insects resemble each other in their life cycle as well as in size and form, but the girdler is black instead of rufous. The normal host is Virginia

Fig. 454. The grape cane girdler, *Ampeloglypter ater* LeC. (Brooks.)

creeper, but it readily attacks grape. It is found primarily in central and eastern United States.

Eggs are laid in late spring in cane punctures made by the mouthparts. After an egg has been laid, the female continues to make a series of punctures until the cane is encircled, but an egg is placed only in the first puncture (Fig. 454). A similar girdle is made at a point higher on the cane,

causing the tip of the cane to break. The grub feeds in the pith of the cane, and both injured portions may break off. After larval development is completed, pupation occurs, adults appearing again in late summer; these hibernate during the winter. Destruction of the injured canes a few inches below the girdled areas usually controls this insect. It is never a problem in a vineyard following a spray program for more important pests. Guthion is the commonly recommended pesticide.

MINOR GRAPE INSECTS

Grape Leaf Folder, *Desmia funeralis* (Hübner), is widely distributed from coast to coast. It is the larva of a dark brown moth spotted with white (Fig. 455). Full-grown caterpillars are $\frac{3}{4}$ inch long, light green with faint dark markings. They feed on the tissue inside folded portions of the leaves and rarely become numerous in sprayed vineyards. The winter is passed in the pupal stage in the folded and fallen leaves; the moths, emerging in the spring shortly after grape foliage appears, lay their eggs on the leaves. Newly hatched larvae soon begin feeding and folding the leaves. There are two generations each season with a third in more southern areas. If chemical control measures are necessary, DDT, carbaryl, parathion, and lead arsenate have been used with success. Evidently the grape spray programs of eastern United States keep this insect controlled since no reports of its activity have been indicated.

References: *J. Econ. Ent.*, 41:441–442, 1948; *Calif. Agr. Exp. Sta. Leaflet* 79, 1966.

Fig. 455. The grape leaf folder, *Desmia funeralis* (Hübner); *a*, male; *b*, female; *c*, larva; *d*, head and thoracic segments of larva, enlarged; *e*, pupa; *f*, tip of pupa, enlarged; g, grape leaf folded by larva. (U.S.D.A.)

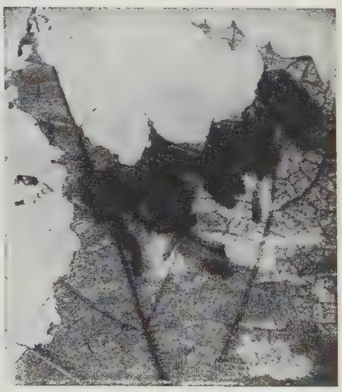


Fig. 456 The grape leaf skeletonizer, *Harrisina americana* (Guér.).

Grape Leaf Skeletonizer, *Harrisina americana* (Guér.), occurs rather widely in the eastern half of the United States. It is rarely noticed except on wild grape and on vines grown in home gardens. Its yellow larvae attract attention by their habit of feeding in groups. Often several worms feed side by side in a row extending across a leaf (Fig. 456). Young larvae consume only the upper surface, but the last instars may eat the entire leaf. When fully grown they are slightly more than $\frac{1}{2}$ inch long. The adult is a small, smoky black, narrow-winged moth. Winter is passed as pupae in cocoons on leaves and in debris on the ground. Adults appear late in the spring and lay their lemon-yellow eggs in clusters on the lower leaf surfaces. There are two and a partial third generation each year. Another species, the western grape leaf skeletonizer, *H. brillians* Barnes & McDunnough, occasionally develops to pest proportions in the West. It has habits and a life cycle like its congener. Vineyards receiving the regular sprays for important grape pests are not troubled with skeletonizers.

Achemon Sphinx, *Pholus achemon* (Drury), is one of the several large sphinx caterpillars or hornworms which sometimes are found feeding on grape foliage (Fig. 457). Other species are *Pholus vitis* L. and the hog caterpillar, *Ampelophaga myron* Cramer. These insects also feed on Virginia creeper. Still other caterpillars in considerable variety feed on grape foliage. The eight-spotted forester, *Alypia octomaculata* (F.), a day-flying black moth with large orange-yellow spots, is common. The grapevine looper, *Lygris diversilineata* (Hbn.), is a measuring worm which may sometimes cause defoliation in unsprayed vineyards. The grape plume moth, *Pterophorus periscelidactylus* Fitch, produces small caterpillars which feed on and web the terminal leaves and shoots as well as the blossom clusters. All these caterpillars are usually listed as grape pests. They are seldom of importance but are found now and then on unsprayed grapes and related hosts. They are never a problem in sprayed vineyards.

Grape Blossom Midge, *Contarinia johnsoni* Felt, is one of the gall gnats. It has at times been a pest in the grape vineyards of western New York. Early varieties are more subject to attack. The midge adults lay their eggs in the unopened buds, and in a few days small orange-red maggots begin feeding inside, causing the buds to shed, thus thinning the bunches of grapes. In two weeks the maggots are fully grown, and then drop to the ground, remaining in the soil until the following spring when pupation and transformation to adults occur. The spray programs indicated for berry moths and leafhoppers seem to control this pest also.

Raisin Moth, *Cadra figuliella* (Gregson), is related to some of the stored product insects, and actually becomes one itself. It is a small, narrow-winged gray moth, which infests the fruits on the vines in California. The larvae may be found on foliage but are noticed chiefly feeding on the

Fig. 457. The achemon sphinx, *Pholus achemon* (Drury): *a*, moth; *b*, egg; *c*, young larva; *d*, mature larva; *e*, pupa; *f*, parasitized larva; all natural size. (U.S.D.A.)

clusters of developing grapes which they cover with disfiguring webs. Considerable destruction of fruit is effected in this way. They continue their feeding in the fruits during drying operations and in storage. Fruits which dry in the shade under trees or vines are most often attacked; fruits exposed continuously to the sun breed few moths. Abundance of the raisin moth in the field can be greatly reduced by sanitation measures in and around the packing and drying houses. Control in storage can be effected by fumigation (p. 573).

Spotted Pelidnota, *Pelidnota punctata* (L.), is a pale yellow beetle spotted with black, of the form of May or June beetles but considerably larger. These beetles occur generally west to the Rocky Mountains. They attack

grapes in midsummer, feeding on foliage and fruits. They are never a problem in sprayed vineyards, but unsprayed isolated vines are occasionally fed upon.

Grapevine Aphid, *Aphis illinoisensis* Shimer, is reported from most of the eastern half of the United States and attacks both wild and cultivated grapes. It is seldom a problem in sprayed vineyards. The winter host is viburnum, and on plants of this group the winter eggs are laid. Hatching begins in early spring and, after a few wingless parthenogenetic generations, winged individuals are produced that migrate to grape, where colonies of this dark brown aphid develop on the young shoots and leaves. When very abundant they may infest the fruit clusters causing some of the grapes to drop. In the fall winged individuals again develop that return to viburnum and produce the egg-laying females. Natural enemies of aphids such as lady beetles, aphid lions, syrphid fly larvae, and parasites usually keep this insect controlled, but if chemicals should be needed to check an infestation use malathion or parathion.

Reference: *U.S.D.A. Farmers' Bul.* 1220, 1926.

Grape Colaspis, *Colaspis flavida* (Say), feeds on a wide variety of hosts in both the larval and the adult stages. Adults feed on the foliage of strawberry, grape, corn, beets, potato, melons, roses, okra, and many leguminous plants. In addition to grapes and strawberries, the larvae feed on the roots of various clovers, soybeans, rice, and grasses. The larvae are sometimes called clover white grubs because of their resemblance to these insects. Adults are light brown and about $\frac{3}{16}$ inch in length.

Partly grown larvae pass the winter in the soil, complete their development in the spring, pupate, and emerge as adults in June. Eggs are laid during the summer and fall, the newly hatched larvae feeding until cold weather. Only one generation develops each season.

Newly set strawberry plants are commonly attacked by the grape colaspis if the planting is made after a spring-plowed leguminous crop. Injury seldom occurs if the plowing is done in the fall. Soil chemicals as recommended for white grubs have controlled this insect.

Reference: *Ark. Agr. Exp. Sta. Bul.* 624, 1960.

20

Insects Injurious to Small Fruits

STRAWBERRY WEEVIL

Anthonomus signatus Say, Family Curculionidae

This little weevil is found from Canada and the Atlantic Coast to Texas, and north through the Mississippi Valley. It is apparently a native insect which feeds on wild strawberry, dewberry, brambles, and redbud, in addition to cultivated strawberries.

The adult is a brown snout beetle with black patches on the wings, and is scarcely $\frac{1}{10}$ inch in length (Fig. 458). Larvae are correspondingly small, white, thick-bodied, curved grubs. Hibernating beetles emerge in early spring, feeding first on whatever food plant is available. When strawberry blossom buds are formed the beetles lay eggs in the feeding punctures that they make in this part of the plant. Then they move down a short distance and partly cut through the stem, causing the bud to wilt, fall over at a sharp angle, or drop to the ground. Because of this habit the insect is

Fig. 458. The strawberry weevil, *Anthonomus signatus* Say. (Baerg, Ark. Agr. Exp. Sta.)

Fig. 459. The strawberry weevil: *a, b,* injury to buds and stems; *c,* outline of egg; *d,* larva; *e,* head of larva; *f,* pupa; *g,* bud opened to show egg on left and punctures made by snout of beetle through petals. (U.S.D.A.)

sometimes known as the clipper (Fig. 459). In the buds the larvae complete their development before mid-summer, change to pupae, and emerge as adults. After a short feeding period they go into hibernation; there is only one generation each year. Pistillate varieties of strawberries are relatively immune from attack since only varieties with staminate flowers seem to furnish the proper food or developmental conditions.

If control measures are applied in the spring at the first sign of adult weevil activity, very little crop damage accrues and no dangerous residues on the berries result. Recommended insecticides are methoxychlor, DDT, chlordane, and carbaryl.

References: *J. Econ. Ent.,* 43:222–223, 1950; *Purdue Agr. Ext. Leaflet* 344, 1952; *U.S.D.A. Farmers' Bul.* 2184, 1965; *Ohio Res. Bul.* 987, 1966.

STRAWBERRY LEAF ROLLER

Ancylis comptana fragariae (W and R.), Family Olethreutidae

The leaf roller, or leaf folder, is present in Canada and a large part of the United States from the Mississippi Valley eastward. Damage results from the larvae feeding within the folded, rolled, or webbed leaves causing them to turn brown and die.

The adult is a rusty brown moth with markings of light yellow and a

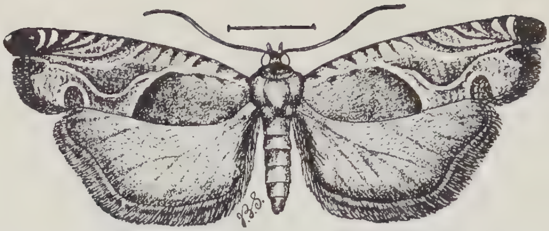


Fig. 460. The strawberry leaf roller moth, *Ancylis comptana fragariae* (W. and R.). (J. B. Smith.)

wing expanse of $\frac{1}{2}$ inch or more (Fig. 460). The larvae are pale green to brown and exceed $\frac{1}{2}$ inch in length when fully grown.

Both larvae and pupae hibernate, the pupae in folded leaves and the larvae sometimes in the same situation and sometimes in other shelters, which they construct in the litter near the plants. Adults emerge in April and early May, and lay tiny eggs on the foliage. Hatching occurs in a week or more, and the larvae complete their development, pupate, and emerge as adults in forty to fifty days. There are two generations and a partial third each season.

To destroy the larvae that eventually hibernate so that no treatments need be applied the following spring, make two spray or dust applications in August at fifteen-day intervals with TDE or DDT at 1 pound per acre. If this is not done and treatment is indicated in the spring, apply carbaryl, malathion, guthion, or parathion just as the first blooms appear. For controlling the pest after berries are forming or for everbearing strawberries, use carbaryl, malathion, guthion, or rotenone. Follow the residue precautions on the insecticide label.

References: *Ohio Agr. Exp. Sta. Bul.* 651, 1944; *Purdue Agr. Ext. Leaflet* 344, 1952; *U.S.D.A. Farmers' Bul.* 2184, 1965.

ROOT WEEVILS

Order Coleoptera, Family Curculionidae

These weevils are widely distributed in northern United States and southern Canada. In the Pacific Northwest infestations may become very numerous and correspondingly injurious. Besides strawberries, they also attack raspberries, loganberries, blueberries, grapes, azalea, Taxus, hemlock, rhododendron, primrose, red clover, grasses, and many other nursery and flower garden plants. Damage is caused by the larvae devouring the roots and the adults feeding on the leaves.

There are four species that cause this damage. They are the strawberry root weevil, *Brachyrhinus ovatus* (L.), the black vine weevil, *B. sulcatus*

Fig. 461. The strawberry root weevil: (left) adult; (right) larva. (Pettit and Downes.)

Fig. 462. The rough strawberry root weevil, *Brachyrhinus rugosostriatus* (Goeze). (Utah Agr. Exp. Sta.)

Fig. 463. The black vine weevil, *Brachyrhinus sulcatus* (F.). (U.S.D.A.)

(F.); the rough strawberry root weevil, *B. rugosostriatus* (Goeze); and the clay-colored root weevil, *B. singularis* (L.) (Figs. 461, 462, and 463).

All these chewing weevils are snout beetles, with hard-shelled bodies and rows of small round pits on the elytra. They are light brown to black and vary in length from $\frac{1}{5}$ to $\frac{2}{5}$ inch, the largest species being the black vine weevil. All the flightless adults are females that reproduce parthenoge-

netically. The white larvae tinged with pink are curved legless grubs with brown heads (Fig. 461).

The life cycles of all four species are very similar. Most of them spend the winter as nearly grown larvae in the soil among the roots of the host plants. In the spring they change to pupae and begin emerging as adults about June. In two or more weeks they begin depositing eggs near the crowns of the plants, each female laying 150 to 200. Hatching occurs in about ten days and the tiny larvae burrow into the soil and feed on the roots. A small percentage of the root weevils overwinter as pupae or adults in the soil. These adults appear in May and soon begin egg-laying. There is usually only one generation per year.

Damage from root weevils can be greatly reduced where new plantings are placed in uninfested soil. In crop rotations, avoid planting a susceptible host after grass or clover sod.

Several insecticides are now recommended for root weevil control. For nurseries or other crops where damage has been severe, soil treatment with 10 pounds of actual chlordane, or 5 pounds of aldrin or dieldrin have been effective. The insecticide should be applied to the land and mixed with the soil by disking or plowing, before planting the susceptible crop. It may reasonably be expected that one treatment will last several seasons. Spraying the host plants before the majority of the adults begin oviposition with 1 pound of actual aldrin, dieldrin, chlordane, or DDT in 100 gallons of water per acre has been done with successful results. For the black vine weevil this period comes about the first of July in northern Ohio. To avoid poisonous residues on fruit crops like strawberries, the first spray or dust application should be made before bloom, the second immediately after harvest is completed, and the third about three weeks later. None of these chemicals should be used after fruits are formed. Where feasible, surface soil treatment just as adult emergence begins is also effective, since migration from the soil is entirely by crawling.

References: *U.S.D.A. Tech. Bul.* 325, 1932; *Farmers' Bul.* 2184, 1965; *Conn. Agr. Exp. Sta. Cir.* 174, 1950; 211, 1960; *Utah Ext. Cir.* 186, 1953; *J. Econ. Ent.*, 46:234–237, 1953; 48:207–208, 1955; *Can. Dept. Agr. Pub.* 78, 1953; 990, 1956; *Ohio Res. Bul.* 987, 1966.

STRAWBERRY CROWN BORER

Tyloderma fragariae (Riley), Family Curculionidae

The crown borer is considered a native American pest. It is found rather generally distributed through the eastern half of the country. Damage is caused by the larvae boring into the crown of the plant (Fig. 464) and feeding on the interior; sometimes the crown is hollowed out so completely that growth is checked or the plant killed. Some injury also

results to the crowns from the feeding cavities made by the adults in which they deposit their eggs. The adults also eat small holes in the leaves.

The flightless adults are dark brown snout beetles having three darker spots on each wing cover, and a total length of about $\frac{1}{6}$ inch. They hibernate during the winter, becoming active about the time strawberries blossom. Egg-laying soon begins and continues into August. The white, curved, legless larvae with dark heads feed in the crowns, becoming fully grown, pupating, and emerging as adults the same summer. After feeding for a period they go into hibernation in any convenient shelter. Only one generation develops each year.

Rotation of the crop effects some control since the beetles migrate only by crawling. Avoid placing new plantings closer than 300 yeards to old plantings or border wastelands containing wild strawberries or cinquefoil. Deep plowing and compacting the soil of each planting after the second crop is harvested will destroy many borers. Care should be taken, in the establishment of new plants, to secure uninfested ones. All these cultural measures, if practiced, will control this insect. However, if these suggestions are not followed and an infestation develops, insecticides will be necessary.

A 5% chlordane dust at 20 pounds per acre or a spray of 2 pounds of 50% chlordane wettable powder in 100 gallons of water per acre has been very effective in control. The application should be made just before

Fig. 464. The strawberry crown borer, *Tyloderma fragariae* (Riley). (Marcovitch, Tenn. Agr. Exp. Sta.)

blooming. Preplant treatment of soil with chlorinated hydrocarbon insecticides as given for root weevils should check this pest.

References: *Ohio Agr. Exp. Sta. Bul.* 651, 1944; *Purdue Agr. Ext. Leaflet* 344, 1952; *U.S.D.A. Farmers' Bul.* 2184, 1965.

STRAWBERRY ROOTWORM

Paria fragariae Wilcox, Family Chrysomelidae

Widely distributed in Canada and the United States, this insect attacks strawberries, raspberries, blackberries, roses, and other plants. Adults feed primarily at night on foliage, and the larvae feed on the roots and crowns of strawberries and related hosts.

The beetles are glistening dark brown with black markings, and are slightly more than $\frac{1}{8}$ inch in length (Fig. 465). The larvae have the appearance of small white grubs, being curved, white, with three pairs of true legs, which help distinguish them from crown borer larvae. Adults hibernate under plant remnants in the field, become active in the spring, feed and lay eggs on the older leaves near the ground. Oviposition may continue until mid-July. Hatching occurs in a week and the larvae, after passing through four instars, pupate and transform to adults. The entire life cycle is completed in about two months, with one generation in the North, two in California, and one and a partial second in North Carolina.

Cultural controls consist of plowing infested fields in early July while the beetles are in the larval stage, and setting new plantings some distance from infested fields or from adjacent favorable hibernating quarters.

Fig. 465. The strawberry rootworm, *Paria fragariae* Wilcox, adult and larva. (U.S.D.A.)

If, before making a new planting of strawberries, the top layers of the soil are treated with a chlorinated hydrocarbon insecticide as given for root weevils, freedom from attack is assured. If this is not done and the insect becomes numerous apply 1 pound of methoxychlor or DDT per acre just before the blossoms open. This will kill adults before they lay many eggs. Another treatment may be applied after harvest if the infestation justifies the cost.

References: *Ohio Agr. Exp. Sta. Bul.* 651, 1944; *Purdue Agr. Ext. Leaflet* 344, 1952; *J. Econ. Ent.*, 46:1101–1102, 1953; *U.S.D.A. Agr. Handbook* 290, 1965.

STRAWBERRY ROOT APHID

Aphis forbesi Weed, Family Aphididae

This aphid is a pest of strawberries primarily in the eastern half of the United States. Both nymphs and adults suck the sap from the roots, and their presence can be detected by the conspicuous abundance of ants.

Winter is passed as shiny black eggs on the stems and foliage of strawberries. In early spring they hatch into blue-green female aphids which feed on new strawberry leaves. Ants, especially the cornfield ant, soon carry them to the roots where repeated generations are produced throughout the summer. These individuals are all parthenogenetic, wingless females which give birth to their young. Winged females (Fig. 466) develop in October which produce sexual individuals that mate and lay the overwintering eggs. The root forms may persist through the winter as more or less active individuals, especially in mild climates.

Usually no aphids are found in plantings that have been treated with chlordane, aldrin, or dieldrin for the control of root weevils (p. 512). The chemicals eliminate the ant population. Spot-treating infested plants or ant nests is of value in small plantings but more satisfactory control results

Fig. 466. The strawberry root aphid, early season forms. (Marcovitch, Tenn. Agr. Exp. Sta.)

from complete treatment of large areas. Dipping plants in demeton before setting in the field is a recommended procedure.

References: *Purdue Agr. Ext. Leaflet* 344, 1952; *U.S.D.A. Farmers' Bul.* 2184, 1965; *Agr. Handbook* 290, 1965; *Calif. Agr. Exp. Sta. Leaflet* 81, 1966.

STRAWBERRY APHID

Chaetosiphon fragaefolii **(Cockerell), FAMILY APHIDIDAE**

Primarily a southwestern species, this aphid does not attack the roots but confines its feeding to the foliage, principally the undersides of the leaves. Besides removal of plant sap, the foliage is often smutted from fungus growth which develops on the honeydew excretion of the aphids. This species also transmits the virus causing the disease known as "yellows." The aphids are small and pale yellow. Recommended insecticides are demeton, diazinon, endosulfan, malathion, parathion, mevinphos, or TEPP.

References: *U.S.D.A. Farmers' Bul.* 2184, 1965; *Agr. Handbook* 290, 1965.

Fig. 467. The raspberry crown borer, *Bembecia marginata* (Harris): *a*, male; *b*, female. (Summers.)

RASPBERRY CROWN BORER

Bembecia marginata **(Harris), FAMILY AEGERIIDAE**

The adults are clear-winged moths having some resemblance to wasps. They are black, with yellow bands on the abdomen, and bands and stripes on the thorax (Fig. 467). Female moths are larger than the males; the former are more than an inch in body length. The larvae reach a length of over an inch and are thick-bodied, soft, and white (Fig. 468). Eggs are laid on the foliage in late summer. On hatching, the larvae crawl down to the base of the canes, excavate small cavities, and remain there in winter. During the following spring and summer they continue their growth, feeding in the crowns and roots. They make large galleries which may be extensive enough to ruin the plants but are smaller than the ones that follow the next summer when the entire crown may be hollowed out. Early in the second summer growth is completed and pupation takes place in the canes, the moths emerging by midsummer and laying their eggs, thus completing the life cycle which requires two years.

No really satisfactory control measures have been developed. Removal

Fig. 468. The raspberry crown borer: larvae, pupae, adults, and injured root. (Lawrence, Wash. Agr. Exp. Sta.)

and burning of all wilting canes in June and July is of some help. Badly infested plantings should be plowed in late fall or early spring, and the canes and crowns gathered and burned. Possibly spraying the canes and bases of the plants during the egg-laying period with diazinon, DDT or parathion, as suggested for the peach tree borer, would be of value.

Reference: *Can. Dept. Agr. Pub.* 880, 1952.

RASPBERRY CANE BORER

Oberea bimaculata (Olivier), Family Cerambycidae

If the tips of young shoots of raspberry, blackberry, and sometimes roses are found wilted and dying in early summer, it is a sign that they have been girdled by the cane borer. This insect is generally distributed from Kansas eastward, and is often quite destructive in the province of Quebec.

The adult is a slender black beetle about $\frac{1}{2}$ inch long, with prominent antennae and usually two black dots on the yellow prothorax. They appear in June and may be present until late August. After laying an egg, the female girdles the cane about $\frac{1}{4}$ inch above and again $\frac{1}{4}$ inch below the egg puncture, causing the tip of the shoot to wilt and die. On hatching, the larvae bore downward in the cane (Fig. 469), passing the winter not far below the point of girdling. The next season they continue boring until the crown is reached; there the second winter is passed at or below ground level. The following spring full growth is attained when the larvae are nearly $\frac{3}{4}$ inch in length. Pupation follows, and new adults begin emerging in June. Two years are required to complete the life cycle.

The best control practice is the destruction of the canes that show characteristic injury. If pruning is done within a few days after the wilted tips

appear, only an inch or so more than the wilted part need be removed. Where this does not prevent serious injury, apply a spray containing 2 pounds of 50% DDT wettable powder, or 4 pounds of lead arsenate plus 4 pounds of hydrated lime in 100 gallons of water per acre. This should be done just before the blossoms open. If it is necessary to spray after the fruit has begun to form, use 5 pounds of derris or cubé powder (5% rotenone) plus 0.5 pound of skim-milk powder in 100 gallons of water. This should be applied when the last petals are falling.

References: *Can. Dept. Agr. Pub.* 880, 1952.

Fig. 469. Young larva and early injury caused by the raspberry cane borer. (Headlee.)

RED-NECKED CANE BORER

Agrilus ruficollis **(Fabr.), FAMILY BUPRESTIDAE**

Although widely distributed in eastern United States and Canada, this insect is seldom of much importance as a pest. The adults feed on foliage, and the larvae produce gall-like enlargements on the cane from their spiral tunnelling within. Affected canes are weakened and may die or produce no fruit. Raspberry, blackberry, and dewberry are the common hosts.

This bronzed, blue-black beetle, with a coppery red prothorax, is slightly more than $\frac{1}{4}$ inch long. The white larva attains a length of more than $\frac{1}{2}$ inch (Fig. 470). Adults are present from May to August, feeding on foliage and ovipositing on canes. The young larvae make spiral burrows just beneath the bark, and when they become larger they also bore in the pith. Winter is passed in the larval stage, with pupation occurring in the spring and new adults appearing in late May. Only one generation develops each year.

Destruction of the infested canes is the simplest remedy, but to be effective this must embrace not only the cultivated plants but also wild hosts in the vicinity. Just before blooming or immediately after harvest is completed, adults can be killed by spraying with 4 pounds of lead arsenate plus 4 pounds of hydrated lime, or 2 pounds of 50% DDT wettable powder in 100 gallons of water per acre.

References: *U.S.D.A. Farmers' Bul.* 1286, 1922; *Can. Dept. Agr. Pub.* 880, 1952.

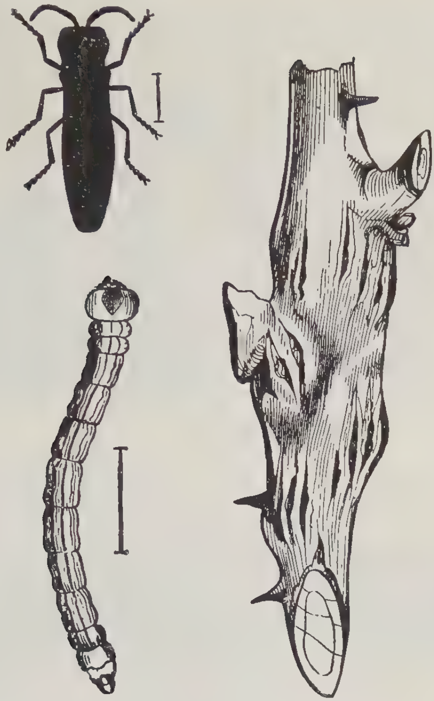


Fig. 470. The red-necked cane borer, *Agrilus ruficollis* (Fabr.); beetle, larva, and injured cane. (Riley.)

RASPBERRY CANE MAGGOT

Pegomya rubivora (Coq.), Family Anthomyiidae

The raspberry cane maggot is prevalent over the entire northern half of the United States and southern part of Canada. It seldom causes serious injury except in British Columbia. Wilted tips of the canes are sometimes cut off almost as cleanly as if the cut were made with a knife; canes of both raspberry and blackberry also show gall-like swellings (Figs. 471 and 472). Both these symptoms are caused by the cane maggot, an insect which resembles the cabbage maggot. The larvae are white, tapered, and scarcely exceed $\frac{1}{3}$ inch in length. The flies are not unlike the house fly but are only about $\frac{1}{2}$ as large and are much more pointed near the tip of the abdomen.

Winter is passed as puparia in the infested canes; the adults emerge in the spring and lay their eggs on the new shoots of brambles. Developing larvae feed in the layer of wood outside the pith, thus girdling the canes. In raspberries the injured tips usually break off; in blackberries this usually does not happen, since the larvae are unable to complete their development

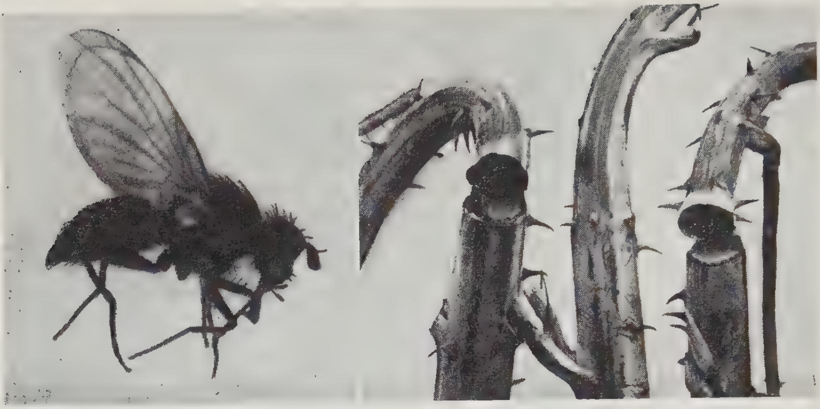


Fig. 471. The raspberry cane maggot, *Pegomya rubivora* (Coq.). (Slingerland.)

Fig. 472. Gall-like swelling on living blackberry canes caused by the raspberry cane maggot. (Lawrence.)

in such plants. The larvae tunnel downward in the canes and when fully grown transform to puparia, which is the hibernating stage.

Since the presence of the insects is indicated by the wilted tips, it is an easy operation to cut off the infested portions a few inches below the girdle and destroy them by burning.

BRAMBLE LEAFHOPPER

Ribautiana tenerrima (H.-S.), Family Cicadellidae

This is a major pest of cane fruits in Europe as well as in parts of the United States and Canada. By sucking the sap from the leaves it prevents

the fruits from developing and ripening, thus reducing the yield. The injury has the appearance of tiny white spots or mottled areas on the leaves.

Adults are about $\frac{1}{8}$ inch long, pale yellow-green, wedge-shaped, with red eyes. The nymphs are similar in shape but are wingless and pale white in color. The winter is passed in the egg stage under the bark of the canes. Hatching takes place usually the first two weeks of May, and the nymphs become fully grown in three or four weeks. Adults are abundant in late June and July, and they lay eggs which result in a second generation. In southern areas there may also be a third generation.

Satisfactory control can be attained by one application of either methoxychlor or DDT at a dosage of 1 pound per acre. Apply when the eggs are hatching, usually during the first two weeks of May or when the fruiting arms are 6 to 8 inches long. In some seasons it may be necessary to make a second application after harvest if the adults are numerous on the leaves of the young canes.

Reference: *Can. Dept. Agr. Pub.* 116, 1950.

RASPBERRY FRUITWORMS

Order Coleoptera, Family Byturidae

These important pests of red raspberries and loganberries are widely distributed in northern United States and southern Canada. Damage to the plants results from both adult and larval stages. In the spring, the adult beetles feed on the young unfolding leaves, buds, and blossom clusters, causing a marked reduction in fruit set. The larvae penetrate the flower buds and developing fruits, often causing them to drop or decay before harvest. Wormy fruits are unmarketable.

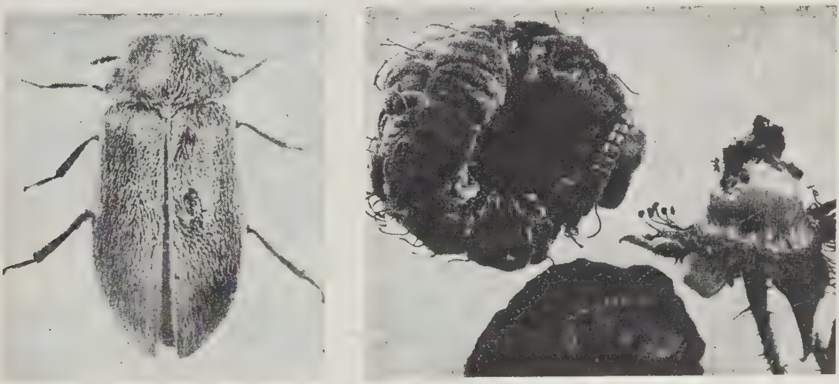


Fig. 473. A raspberry fruitworm; adult and feeding larvae. (Walden, Conn. Agr. Exp. Sta.)

The common species are the western raspberry fruitworm, *Byturus bakeri* Barber, and the eastern raspberry fruitworm, *Byturus rubi* Barber.

The elongate, oval, light brown beetles (Fig. 473), with a slightly pilose surface, are about $\frac{1}{8}$ inch in length. They emerge from the soil in April and May, begin feeding and laying eggs on the blossom clusters, and later on the developing berries. On hatching, the light yellow larvae feed in the blossoms and young fruits, becoming almost $\frac{1}{3}$ inch in length when fully developed. Mature larvae leave the plant, burrow into the soil, and transform into pupae. The pupae change to adults during the summer, remaining in this stage in the soil until the following spring.

Satisfactory control results from application of dusts or sprays containing rotenone, DDT, or lead arsenate. The first application should be made when the blossom buds first appear and the second just before blooming. For dusting, use 0.75 to 1% rotenone, 3% DDT, or a 15–85 mixture of lead arsenate-hydrated lime. Effective concentrations for spraying are 3 to 4 pounds of derris or cubé powder (containing 4% rotenone), 2 pounds of 50% DDT wettable powder, or 4 pounds of lead arsenate to 100 gallons of water. To get better coverage with the sprays, especially those containing rotenone or lead arsenate, the addition of 0.25 to 0.5 pound of soybean flour or neutral spreading agent is recommended. If beetles are present after the fruits are formed, rotenone is the only insecticide suggested.

References: *Conn. Agr. Exp. Sta. Bul.* 251, 1923; *U.S.D.A. Misc. Pub.* 468, 1942; *J. Econ. Ent.*, 41:436–440, 1948; *Can. Dept. Agr. Pub.* 880, 1952.

RASPBERRY SAWFLY

Monophadnoides geniculatus (Htg.), FAMILY TENTHREDINIDAE

This is one of the common pests of raspberries in the north central states eastward to New England and in Canada. The adult is a small thick-bodied black sawfly, little more than $\frac{1}{4}$ inch in length, which lays its eggs in the leaf tissue of the host in May and June. Larvae are light green and marked by conspicuous bristles, which arise from small swellings on the body (Figs. 474 and 475). These larvae may be as much as $\frac{1}{2}$ inch in length. In the course of their development they consume the leaf tissue, and a heavy infestation may result in loss of the crop berries. The larvae complete their feeding in less than two weeks and then estivate in cocoons which they construct in the ground. They remain in these cocoons through the winter and pupate in early spring.

If applications are made within a few days after the blossoms form, sprays or dusts of arsenicals, DDT, or rotenone will control these worms. For spraying, add 3 pounds of lead arsenate, 2 pounds of 50% DDT wettable powder, or 4 pounds of derris or cubé powder (4% rotenone) to 100 gallons of water. For dusting use 1% rotenone or 5% DDT at 30 pounds per acre.

Fig. 474. Larva of the raspberry sawfly. (U.S.D.A.)

Fig. 475. Both sexes of the raspberry sawfly, *Monophadnoides geniculatus* (Htg.). (Lowe, N.Y. Agr. Exp. Sta.)

DDT will also kill adults before egg-laying, which is a distinct advantage. If the infestation is not noticed until after the fruit is set, only rotenone insecticides should be applied because the other chemicals leave poisonous residues.

References: *Can. Dept. Agr. Pub.* 880, 1952; *Calif. Agr. Exp. Sta. Leaflet* 75, 1966.

TREE CRICKETS

Order Orthoptera, Family Gryllidae

The tree crickets are native insects, species of which are to be found in most regions of southern Canada and in the United States. They are minor pests of orchard trees and bush fruits which are damaged primarily by oviposition. Later instar nymphs may feed on the foliage, and the adults feed on both foliage and ripening fruits. Additional injury may result from disease organisms gaining entrance through the egg punctures, and from the splitting of canes by the freezing of moisture which has gained access. Common species are the prairie tree cricket, *Oecanthus argentinus* Saussure, the black-horned tree cricket, *O. nigricornis* Walker, and the four-spotted tree cricket, *O. quadripunctatus* Beutenmüller.

The various species are similar in appearance and development (Fig. 476). Eggs are laid in late summer or early fall, and the winter is passed in this stage (Fig. 477). These eggs hatch rather late in the spring, and the young crickets feed as predators for most of their lives, sometimes eating a small amount of vegetation when they are nearly grown. Adults appear

Fig. 476. Nymphal instars and adult of the black-horned tree cricket. (Parrot & Fulton, N.Y. Agr. Exp. Sta.)

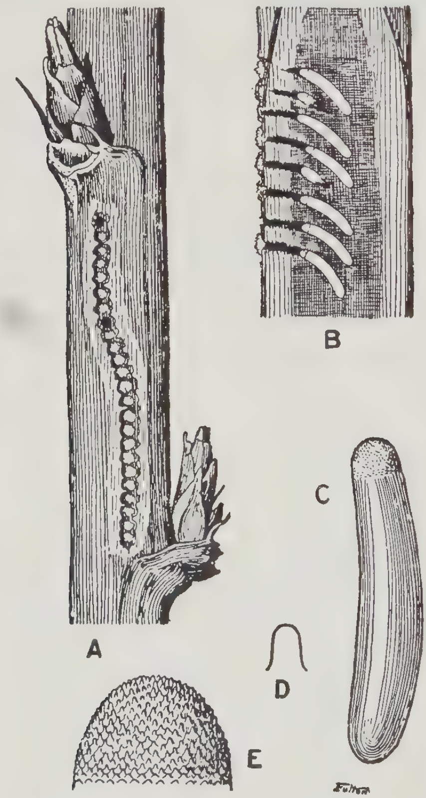


Fig. 477. Raspberry stem injured by the tree cricket; *A*, wound made by egg punctures; *B*, longitudinal section through same, showing eggs; *C*, egg; *D*, *E*, cap of egg. (Fulton.)

in late summer, thus completing the cycle. Only the males are capable of producing the familiar tree cricket song. The prairie tree cricket oviposits primarily in fruit trees or in other solid wood plants and lays its eggs, one in a place, just beneath the bark. The other two species lay their eggs in plants with a pithy center, such as brambles and elder. Raspberry canes are often severely damaged. The eggs are placed in elongated rows, each containing as many as eighty.

Eliminating wild brambles from the vicinity of cultivated raspberries or orchards is of value in preventing injurious populations of tree crickets. Pruning old fruiting canes after harvest and the removal and destruction of egg-infested canes in the spring are recommended practices. Where sanitation measures do not give sufficient control, a spray consisting of either 3 to 4 pounds of lead arsenate plus 0.5 pounds of spreading agent, or 2 pounds of 50% chlordane wettable powder, to 100 gallons of water, applied before bloom and again after harvest, is suggested to eliminate the infestation. A 5% chlordane dust can be applied with advantage in small plantings.

References: *N.Y. Agr. Exp. Sta. Bul.* 388, 1914; *Can. Dept. Agr. Pub.* 880, 1952; *Ann. Ent. Soc. Amer.*, 56:772–789, 1963.

ROSE SCALE

Aulacaspis rosae **(Bouché), Family Diaspididae**

Frequently rose bushes, raspberry and blackberry canes become encrusted with these scale insects. They not only spoil the appearance of the plants but their sucking of plant sap greatly reduces plant vigor. Female scales are almost circular, nearly 2 millimeters in diameter, dirty white, with an

Fig. 478. The rose scale, *Aulacaspis rosae* (Bouché).

Fig. 479. The blackberry leaf miner, *Metallus rubi* Forbes; adult. (N.Y. Agr. Exp. Sta.)

orange-yellow dot in the center. The male scales are much smaller, long and narrow, and snow white. These scales are most abundant in humid situations where the amount of sunlight is reduced (Fig. 478).

Winter is passed as pink eggs under the female scale coverings in some areas; in other regions full-grown females survive. The eggs begin hatching in late May or early June and after the tiny crawlers molt the first time the scale covering begins to form. By July they complete their development, and a second generation develops in August and September.

Remove and burn all heavily infested canes that can be spared. Dormant spraying with 3% oil emulsions, or liquid lime-sulfur diluted 1 to 10, has given effective control. Sprays containing 1 pound of 15% parathion wettable powder, or 2 pounds of 50% malathion wettable powder in 100 gallons of water, applied as the eggs are hatching in the spring, also control this pest.

MISCELLANEOUS PESTS OF BRAMBLES

Blackberry Leaf Miner, *Metallus rubi* Forbes, is a very small sawfly, adults not exceeding $\frac{1}{5}$ inch in length (Fig. 479), the white larvae being nearly $\frac{1}{2}$ inch long when fully grown. The larva mines the leaves of blackberry and at times may cause serious injury. Larvae hibernate in the soil, transform to pupae in the spring, and begin emerging as adults in early June. Two generations are produced annually, the second occurring in mid-August. DDT applied just as the adults are emerging in June or in August should control this insect.

Reference: *N.Y. Agr. Exp. Sta. Bul.* 133, 1928.

Blackberry Psyllid, *Trioza tripunctata* (Fitch), infests blackberries and other brambles. It is found in the northeastern states. Attacks cause injury similar to that of aphids, curling of foliage and distortion of new shoot growth being characteristic symptoms of their presence. Injury is most common in May or June but may recur in early September. Control may be accomplished by the sprays recommended for aphids.

Reference: *N.J. Agr. Exp. Sta. Bul.* 378, 1923.

Redberry Mite, *Aceria essigi* (Hassan) (Fig. 480), causes a condition primarily in Himalaya and Mammoth blackberries known as "redberry disease." It is present when some drupelets on a berry remain red, hard, and sour after the fruit is ripe. The condition is caused by a microscopic mite related to the blister mite of pear; it is apparently an imported species, being known in England. This mite has been injurious in the Pacific Coast areas since 1921. The mites spend the winter in the buds and attack the drupelets soon after the flowers open in the spring. Many overlapping

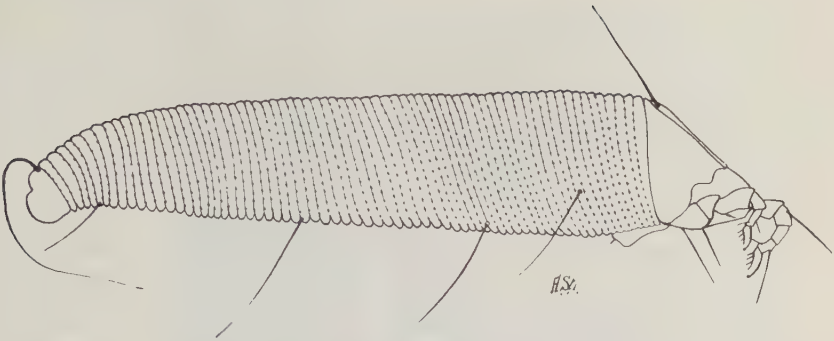


Fig. 480. The redberry mite which causes "redberry disease," primarily in Himalayan and Mammoth blackberries. It is so small it cannot be seen without magnification. Figure greatly enlarged. (Drawing by A. S. Hassan.)

generations develop each summer. Predaceous mites are of some value in checking this pest. Control is accomplished by spraying with 6 to 8 gallons of lime-sulfur solution in 100 gallons of water during the fall after removal of old canes or in the spring at the delayed dormant period. If a second application is necessary at the prebloom period, reduce the amount of lime-sulfur to 2½ gallons.

References: *Wash. Agr. Exp. Sta. Bul.* 279, 1933; 155, 1938; *Tech. Bul.* 6, 1952; *Calif. Ext. Cir.* 87, 1944; *Agr. Exp. Sta. Leaflet* 75, 1966; *Can. Dept. Agr. Bul.* 880, 1955.

Blackberry Gall Maker, *Diastrophus turgidus* Bassett, causes the formation of rather large polythalamous galls on the stems of brambles, usually of the wild species (Fig. 481). The galls are at first green, later red or brown. The causal agent is a tiny gall wasp in the family Cynipidae. These galls often attract attention but apparently do little harm. The gouty gall maker, *D. nebulosis* (O-S.), and the blackberry seed gall, *D. cuscutaeformis* O-S., are related species. Should control measures be necessary remove the galls by pruning and then destroy them.

CURRANT FRUIT FLY

Epochra canadensis (Loew), Family Tephritidae

Found throughout the northern and western states, this insect attacks the fruits of currants and gooseberries in the larval or maggot stage. The adult is ⅓ inch in length, yellow-bodied with darker shadings and conspicuously banded wings (Fig. 482).

The insect hibernates in the pupal stage in the soil. Adults appear in the spring and lay their eggs under the skin of well-formed berries in which the larvae feed. Their presence is indicated by a dark spot on the berry which may be surrounded by red coloration. Usually the infested

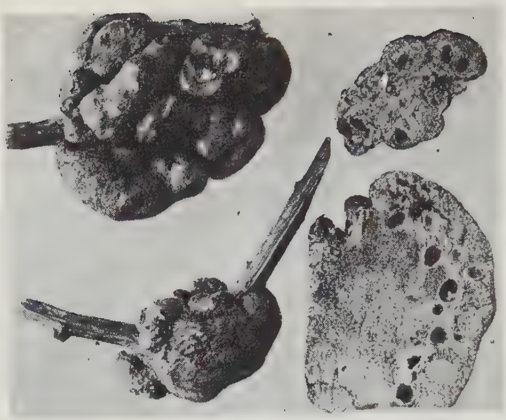


Fig. 481. Galls of the blackberry gall maker, *Diastrophus turgidus* Bassett.

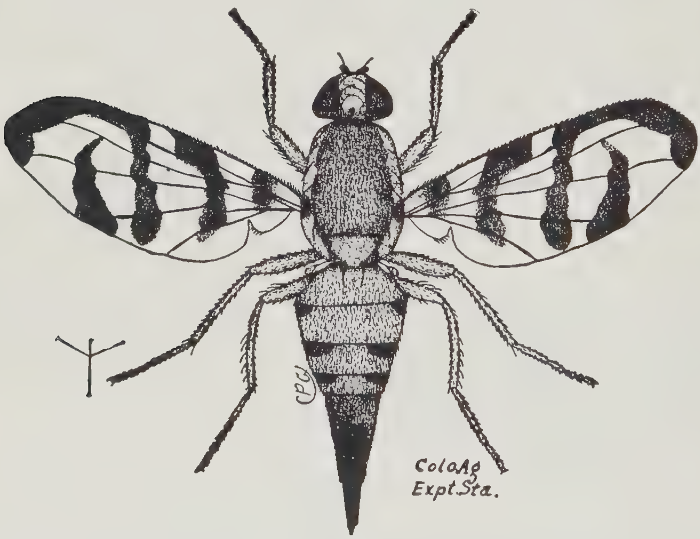


Fig. 482. The currant fruit fly, *Epochra canadensis* (Loew). (Colo. Agr. Exp. Sta.)

berries fall off before the larvae are fully developed and their feeding continues on the ground for a few days before they enter the soil and change to puparia.

Widely advocated control measures are the destruction of all infested berries before the larvae leave them and the cultivation of the soil con-

taining the puparia. Early-maturing varieties will escape much of the injury done by the fruit fly. Properly timed sprays or dusts are said to control this insect. Applications should be made just as the first adults appear, to kill them before egg-laying begins. This is the period when 80% of the blossoms have withered and fallen; a repeat application is usually needed ten days later. Suggested insecticides are rotenone, methoxychlor, malathion, or carbaryl.

References: *Can. Dept. Agr. Pub.* 46, 1951; *Wash. Agr. Exp. Bul.* 155, 1938; *Maine Agr. Exp. Sta. Rept.*, 1896.

IMPORTED CURRANT WORM

***Nematus ribesii* (Scop.), Family Tenthredinidae**

The most conspicuous and by far the best known of the currant pests is this sawfly larva, which appears in great numbers and devours the foliage before ripening of the fruits. Gooseberries are also a favored host. This insect was imported from Europe before the Civil War and has become generally distributed in southern Canada and the United States.

The adult sawflies, nearly the size of the house fly and of a general dark color (Fig. 483), emerge about the time the foliage of the host plants appears and, when the leaves are well grown, lay rows of watery-white eggs along the veins. From these hatch the green, spotted caterpillar-like larvae which consume the foliage. In the last instar these larvae are light green in color (Fig. 484). Pupation takes place in the litter on the ground and adults emerge soon afterwards. A second generation appears about July; possibly because of natural enemies this generation is usually so small as to escape notice. The pupae from the second generation hibernate.

Since the worms do their damage and attract notice just about picking time, the insecticides chosen must not leave a residue poisonous to man. A dust containing 0.75% rotenone or a spray containing 4 pounds of derris or cubé powder (4% rotenone) in 100 gallons of water fulfills the residue requirement and gives effective control. Pyrethrum dusts or sprays may be substituted for rotenone. DDT or lead arsenate at standard dosages are

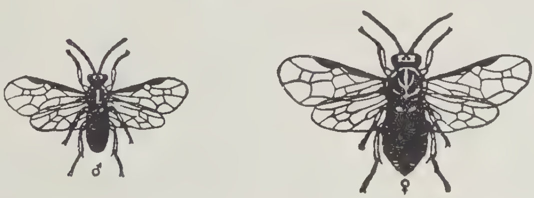


Fig. 483. Male and female adults of the imported currant worm. (Lugger.)

Fig. 484. The imported currant worm, (left) and the currant spanworm, (right). (U.S.D.A.)

effective in controlling this pest but because of their poisonous residues should be applied only for very early-season infestations or at the post-harvest period.

CURRANT SPANWORM

Itame ribearia **(Fitch), Family Geometridae**

The adult of the spanworm is a rather slender-bodied moth with broad yellow wings marked with black. The looping larvae are light-colored with many prominent black dots, having only two pairs of abdominal prolegs (Fig. 484). They devour the foliage of currants and gooseberries, and sometimes blueberries and huckleberries as well. Like other loopers they have the habit of dropping from the food plants on silken threads when disturbed.

Eggs are laid on the twigs or stems about midsummer and do not hatch until the following spring, when the plants are approaching full foliage. Feeding continues for almost a month, and pupation takes place in the soil. Only one generation occurs each year.

While the fruits are forming or nearly ready for harvest, control should be secured by rotenone dusts or sprays, as given for the imported currant worm. DDT or lead arsenate at standard dosages may be used for the newly hatched worms if they are noticed soon enough, since the fruits are not yet formed at that time.

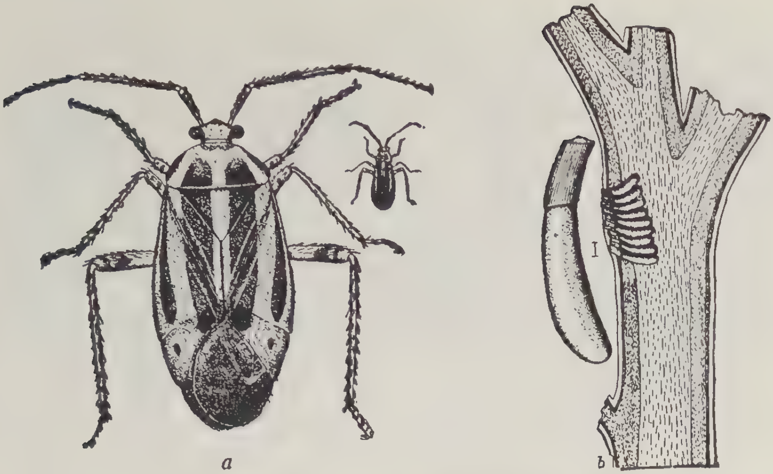


Fig. 485. The four-lined plant bug, *Poecilocapsus lineatus* (Fabr.): *a*. adult; *b*, cross-section of stem showing eggs in position and a single egg greatly enlarged. (Slingerland.)

FOUR-LINED PLANT BUG

Poecilocapsus lineatus **(Fabr.), Family Miridae**

This bug is a general feeder, attacking weeds, legumes, fruits of many sorts, and ornamental and vegetable garden plants, but it is usually listed as a pest of currants (Fig. 485). Both nymphs and adults suck plant sap from the leaves causing distortion, curling, and browning on some hosts (Fig. 486); on others spotting of the leaf surface is the characteristic damage.

The adult is $\frac{1}{4}$ inch in length, yellow-green with four dark stripes on the back. Eggs are placed in the stems of both woody and herbaceous plants, as shown in Fig. 485, and the insect passes the winter in this stage. The orange nymphs appear in the spring and feed on the leaves of the plants in which the eggs were deposited. This causes an early concentration on such hosts as currants, the stems of which are attractive to egg-laying females. Most of the damage is done by these early individuals; later the bugs disperse and the damage is little noticed. There is only one generation each year.

Since the eggs hatch soon after foliage appears in the spring this insect can be controlled by dusting or spraying with chlordane, DDT, methoxychlor, malathion, or carbaryl at that time, if currants are the host attacked. Flowers may be treated any time that damage is noticed.

Fig. 486. Currant leaves killed by the four-lined plant bug. (Slingerland.)

Fig. 487. Currant foliage curled by aphids. (Lowe.)

CURRANT APHID

Cryptomyzus ribis (L.), Family Aphididae

Early-season foliage of currants, gooseberries, and snowball is often distorted due to the extraction of plant sap from the undersurface by this aphid (Fig. 487). Other species than the one named are found from time to time on these hosts.

Winter is passed as tiny black eggs on the currant stems. When leaves appear in the spring these eggs hatch into green, wingless, female aphids which, when fully grown, give birth to succeeding generations. By early summer winged forms are produced that fly to weeds or other hosts and continue their reproduction. In the fall winged migrants are again produced that return to currants and give birth to males and females which, on reaching maturity, mate, the females depositing the overwintering eggs.

This aphid may be controlled by dusting or spraying with malathion at the time the eggs hatch in the spring.

Reference: *N.Y. Agr. Exp. Sta. Bul.* 517, 1924.

CURRANT STEM GIRDLER

Janus integer (Norton), Family Cephidae

This insect is generally distributed in northern and eastern United States and attacks poplar and willow trees in addition to currants. Damage is caused by the adult sawflies girdling the canes as a result of their egg-laying punctures. The injury is seen in late spring and is indicated by drooping

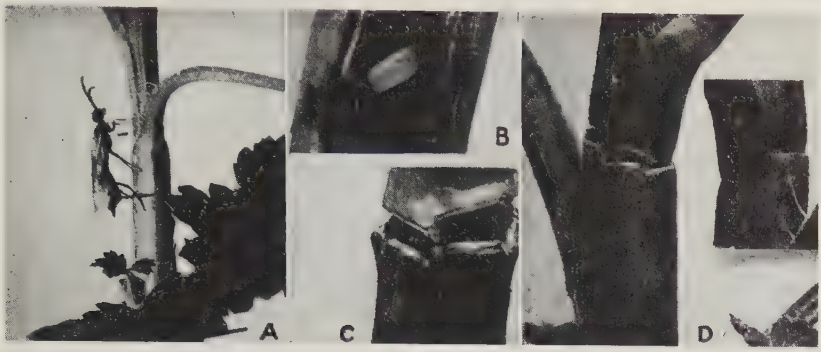


Fig. 488. The currant stem girdler, *Janus integer* (Norton): *A*, female at work girdling a currant stem, natural size; *B*, egg; *C*, stem cut open to show egg; *D*, girdled portion of stem, much enlarged to show character of girdle. (Slingerland.)

and wilting shoots of the new growth. Additional damage is caused by the pale yellow larvae tunnelling in the canes. They remain in their tunnels throughout the summer and winter, pupating in the same situation in the spring. There is a single generation each year. The adult, egg, and damage are illustrated in Fig. 488.

Control may readily be accomplished by the destruction of the infested canes which are easily recognized. If this is carefully done no other control will be necessary.

CURRANT BORER

Ramosia tipuliformis (Clerck), Family Aegeriidae

This well-known European insect is widely established in this country and tunnels the canes of currants and gooseberries in the larval stage. Red currants are the most susceptible host.

The adult is a relative of the borers attacking peaches. It is a small moth with wings almost devoid of scales and a spread not exceeding an inch, the general appearance being somewhat wasplike (Fig. 489). The moths appear in late May or early June and deposit their eggs on the canes. Hatching takes place normally in ten or more days when the pale yellow larvae bore into the canes and tunnel in the pith and wood (Fig. 490). This often causes yellowing of the foliage and sometimes death of the canes. Decreased vigor of surviving canes also reduces the yield. Larvae feed all summer and pass the winter in their tunnels. In early May they pupate, and adults begin emerging about two weeks later, only one generation developing each year.

Destruction of the infested canes provides a simple remedy, but this is

Fig. 489. The currant borer, *Ramosia tipuliformis* (Clerck), adult. (Beutenmüller.)

Fig. 490. The currant borer; adults on foliage and larva in tunnel in stem.

often not practical in commercial plantings because of the lack of sufficient labor competent to do the work and the expense involved to make the practice effective. A high degree of control can be effected by one application of a spray containing 1.5 pounds of 15% parathion wettable powder in 100 gallons of water, ten to fourteen days after the first moths emerge. Laboratory experiments reveal that parathion is highly toxic to the eggs, suggesting that thorough coverage of the canes with the spray is needed for maximum effectiveness. Metacide and diazinon are other control chemicals.

Reference: *J. Econ. Ent.,* 46:394–400, 1953; 57:123–130, 1964.

GOOSEBERRY FRUITWORM

Zophodia convolutella **(Hübner), FAMILY PYRALIDAE**

Widely distributed from the northeastern states to Utah and the Northwest, this insect attacks both gooseberries and currants. Damage results when the larvae bore into the fruits, which they may completely hollow out. One larva may be responsible for the destruction of several berries during the course of its feeding.

The adult is a moth with a wing expanse of nearly an inch. The wings are ash-colored with dark markings. Larvae at maturity are green with a yellow tinge and a pink cast; along the sides are darker lines or stripes. The winter is spent in the ground or under litter in the pupal stage. Moths emerge and lay their eggs in the flowers of gooseberries. On hatching, the larvae bore into the developing fruits. Spraying or dusting with rotenone is the commonly recommended control measure and two applications are usually required.

21

Insects Injurious to Citrus

Like all other crops citrus is attacked by many pests. Only the important ones are discussed in this chapter. For further information, consult Ebeling* and the publications of state experiment stations where citrus is grown. Many of these insects are also pests of plants in the greenhouse.

PURPLE SCALE

Lepidosaphes beckii **(Newman), FAMILY DIASPIDIDAE**

The purple scale is one of the oystershell scales, so-called because its shape somewhat resembles the shell of the oyster. This species is purplish brown and attains 2 to 3 millimeters in length (Fig. 491); it is slightly narrower in form than the average of the better known oystershell scale of northern fruits. This scale attacks citrus in Florida and in California, especially in the coastal areas.

Infestations of these insects suck sap from the foliage and branches, then spread to the fruits where contamination and disfiguration reduce their market value.

Where there is any hibernation period for the scale it is passed in the egg stage, the eggs being produced and sheltered under the scale covering the female insect. Eggs hatch in early summer; there are three or more generations each year with a tendency toward some overlapping.

Natural enemies include the lady beetles, *Scymnus marginicollis* Mann., *Lindorus lophanthae* (Blaisd.), and *Chilocorus stigma* (Say), along with the predatory thrips, *Aleurodothrips fasciapennis* Franklin, a lacewing, *Chrysopa lateralis* (Guerin), and various species of predaceous mites. Parasites include *Prospaltella aurantii* (Howard), *Aspidiotiphagus lounsburyi* (Berlese and Paoli), *A. citrinus citrinus* (Crawford), and *Aphytis lepidosaphes* Compere. Since the latter species was introduced into Florida, purple scale has been reduced to the status of a minor citrus pest.

In California, an effective treatment has been tent fumigation with

* Walter Ebeling, *Subtropical Fruit Pests*, Univ. Calif. Press, 1959.

Fig. 491. The purple scale, *Lepidosaphes beckii* (Newman). On grapefruit.

HCN. This control method has been largely replaced by thorough coverage with summer to fall sprays of 2% light medium or medium grade oil emulsions, or 1.6 to 1.8% emulsive oils. Combination sprays of these oils plus ethion, parathion, malathion, or guthion have also been employed successfully during the postbloom period. These are all considered emergency treatments to kill off scale populations. Parathion and malathion can also be applied alone or as mixtures during the postbloom period and are considered to be important in preventing the development of scale infestations. Oil sprays improperly used may impair the quality and appearance of the fruit as well as increase the susceptibility of trees to cold injury.

References: *J. Econ. Ent.*, 43:305–309, 1950; *Proc. Fla. State Hort. Soc.*, 64:66–71, 1951; *Fla. Agr. Exp. Sta. Bul.* 479, 1951; *U.S.D.A.* E-870, 1953; *Agr. Handbook* 290, 1965; *Calif. Citrus Exp. Sta. Pest Cont. Guide*, 1965; *Fla. Citrus Com. Spray Prog.* 1964.

CALIFORNIA RED SCALE

Aonidiella aurantii (Maskell), Family Diaspididae

The red scale, as this species is most often called, is one of the larger armored scales. The females are sometimes 3 millimeters in diameter, the average size being closer to 2 millimeters; males are still smaller and are oval in shape. The circular-shaped females are red, the color showing through the thin scale covering.

Introduced into this country from Australia, the red scale now occurs in California and the Gulf states, and in greenhouses over the country. There are numerous host plants and it is injurious in California to several decid-

uous fruits as well as being one of the most destructive citrus pests of the region.

The females of this scale give birth to young. There are three or four overlapping generations each year. The scale feeds on all parts of the plant, but it is most numerous on foliage, fruits, and younger branches. Lemons are said to be the favorite food plant but all citrus may be badly injured. The salivary secretions injected while feeding seem to produce a toxic effect on the plants attacked.

The lady beetles, *Chilocorus stigma* (Say), *Lindorus lophanthae* (Blaisdell), and *Microweisia coccidivora* (Ashmead) are important in natural control of this insect in the United States. Two introduced eulophid parasites, *Aphytis lingnanensis* Compere and *A. melinus* DeBach have been effective in reducing red scale populations in California.

Chemical control measures for this scale insect are the same as those given for purple scale. In tests, dimethoate has shown promise for the control of this pest.

References: *J. Econ. Ent.*, 43:610–614, 1950; 47:100–102, 1954; 57:322–324, 1964; *Calif. Agr.* 16(12):2–3, 1962; *Calif. Citrus Exp. Sta. Pest Cont. Guide*, 1965.

YELLOW SCALE

Aonidiella citrina (Coq.), Family Diaspididae

This scale has been listed as a variety of California red scale and as a separate species. It differs from the red scale in that it is less red and has a more transparent scale covering. Its distribution and habits also vary somewhat from those of the red scale. Yellow scale is most abundant in the interior districts of California and tends to feed on foliage and fruits rather than on twigs and branches. All citrus may be badly injured but oranges are said to be a favored host. The life cycle is the same as for California red scale.

Natural enemies include the parasites, *Comperiella bifasciata* Howard, *Aspidiotiphagus citrinus* (Craw.), and *Prospaltella aurantii* (Howard).

Chemical control is the same as for the California red scale.

FLORIDA RED SCALE

Chrysomphalus aonidum (L.), Family Diaspididae

This species has been one of the two most destructive scale insects in Florida. Where it is established and favored by a succession of good seasons it may develop into the most serious pest of citrus; in other localities it may be absent or rare. Since it tends to feed on fruit and foliage rather than on wood, it is greatly reduced by freezing weather, which results in the defoliation of citrus. This accounts, in part at least, for its periodical scarcity. In California the species has never become established except in

greenhouses. The insect is similar in form to the California red scale, but its scale is dark red or brown and the insect beneath is yellow rather than red. The introduction of the parasite, *Aphytis hóloxanthus* DeBach, into Florida has reduced populations of this scale to the point that it is no longer a problem.

Control is accomplished with oil or parathion sprays as recommended for purple scale if chemical controls become necessary. The preferred time of application is June 15 to August 1.

OTHER ARMORED SCALES

Order Homoptera, Family Diaspididae

Chaff Scale, *Parlatoria pergandii* Comstock, is primarily a pest of citrus in the Gulf Coast states, but it also is occasionally a pest of ornamentals both inside and outside greenhouses. Adult females are dark purple and have a gray-brown scale covering, nearly circular in shape. The male scale

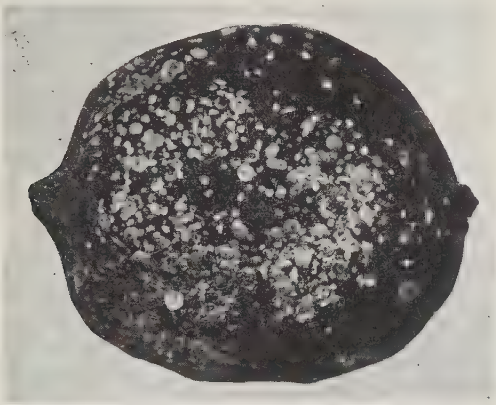


Fig. 492. The chaff scale, *Parlatoria pergandii* Comstock.

covering is much smaller, narrow in form, and white (Fig. 492). This is an egg-laying species and four generations per year may develop. Control is the same as for other armored scales.

Dictyospermum Scale, *Chrysomphalus dictyospermi* (Morgan), is a species with wide distribution in the world. It attacks oranges, lemons, grapefruits, tangerines, avocados, and a number of other hosts both inside and outside greenhouses. The scale covering varies from yellow-brown to deep brown for the immature insects and shades of gray to dark brown for the adults. All stages beneath the scale are yellow. Female scale coverings are circular; those of the male are smaller and more oval-shaped. This

oviparous species produces three to six generations each year, and is controlled in the same manner indicated for other armored scales.

Glover Scale, *Lepidosaphes gloverii* (Packard), occurs in Florida and in a small area in California. It may develop on citrus along with purple scale, which it resembles except for its narrower form. The eggs are placed in two rows beneath the scale covering, whereas in the purple scale they are irregularly placed. This scale is sometimes called "long scale." It is controlled by the same insecticides recommended for purple scale.

Greedy Scale, *Hemiberlesia rapax* (Comstock), resembles ivy scale (p. 386), being light gray, but the scale covering of the female is strongly convex and the yellow-brown nipple is off to one side. Primarily a greenhouse pest in many parts of the United States, it is also found outdoors in California and other regions. It occurs on a wide variety of woody ornamental plants, and occasionally on citrus. Control is the same as for other armored scales.

Citrus Snow Scale, *Unaspis citri* (Comstock), is world-wide in distribution and is considered a severe problem in the northeast portion of the Florida citrus belt. It is very destructive, often killing large branches and sometimes young trees. The female scale covering is oystershell-shaped but is broader at the base than the purple scale. The males are small, slender, ridged, and white, which is the basis for the common name. Control is accomplished by thorough coverage with the insecticides recommended for other armored scales. In Florida, oil sprays have been the least effective of the materials listed.

BLACK SCALE

Saissetia oleae (Bernard), Family Coccidae

The black scale is an unarmored species of tropical origin. It is one of the most widespread and destructive citrus scales in California. In Florida and other Gulf states it is becoming more of a problem, especially on grapefruit. Black scale may become a serious greenhouse pest.

It is a large black or dark brown species, often reaching $\frac{1}{4}$ inch in length; the average size, however, is somewhat smaller (Fig. 493). Male scales are smaller and much more flattened than the females. Except in some coastal areas of California, the black scale has only one generation annually. The white-to-reddish orange eggs are deposited under the shell-like dorsal wall of the female scale. The shrivelled remnants of the undersurface of her body can be found inside, near the peak of the dorsal wall. Most eggs are laid in May and June but the period may extend from April to September. Egg-laying occurs again in late fall in the two-generation area. Hatching may occur in sixteen days or be extended over a period of six weeks in cold weather. The young scales migrate over the plant before settling on the

Fig. 493. Black scale, *Saissetia oleae* (Bernard).

foliage and green twigs to feed. This is the important period for dissemination. Most of the scales migrate to the twigs and branches after the second molt.

As in other scales, injury consists of removal of great quantities of plant sap which may result in stunting, defoliation, or death of branches. In addition, a copious supply of honeydew is excreted which serves as a medium for the development of sooty fungus. This blemishes the fruits and may affect the photosynthetic processes of the plant when it covers the leaf surfaces.

There are numerous parasites and predators of the black scale. Some important parasites are *Scutellista cyanea* Mots., *Aphycus helvolus* Compere, *Aphycus stanleyi* Compere, and numerous species of *Coccophagus*. Predators include aphid lions, syrphid fly larvae, and lady beetles.

Black scale is controlled with the same insecticides as outlined under purple scale with the following additional recommendations. DDT or carbaryl are suggested for application soon after the major period of egg hatch. Do not apply these chemicals during bloom period. Sometimes DDT is used in combination with parathion; other combinations are DDT or parathion mixed with horticultural grade kerosene, or DDT, carbaryl, or rotenone mixed with mineral oil emulsions. A postbloom or mid-May spray of guthion is the preferred method of control in Florida.

References: *U.S.D.A. Agr. Handbook* 290, 1965; *Calif. Citrus Exp. Sta. Pest Cont. Guide*, 1965.

CITRICOLA SCALE

Coccus pseudomagnoliarum (Kuwana), Family Coccidae

This unarmored scale is supposed to have been imported from Japan sometime during the present century. It exists only in the dry interior valleys of Arizona and California and attacks the wood and foliage of all kinds of citrus; it has also been found on a few other plants growing near

citrus trees. Considerable quantities of honeydew are produced, disfiguring the fruits of citrus especially when sooty fungus develops on it.

The scale is quite flat and transparent while on summer foliage, becoming gray with approaching maturity. Egg-laying takes place in the spring and early summer and extends over a period of nearly four months. The first molt occurs a month after the eggs hatch, the second a month later. Migration to the twigs begins in November and continues throughout the winter and spring. Maturity is reached in late April or May. Only one generation develops each year.

Important parasites are *Aphycus luteolus* Timb., *A. stanleyi* Compere, *A. helvolus* Compere, and species of *Coccophagus*.

This scale is controlled in the same manner as that outlined for black scale.

COTTONY-CUSHION SCALE

Icerya purchasi Maskell, FAMILY MARGARODIDAE

The cottony-cushion scale is commonly regarded as a pest of citrus, but it may infest several kinds of fruit and shade trees, ornamentals, as well as other plants. It was introduced into California in 1868, on acacia, and subsequently into Florida where the infestation has never become a problem. Damage from this insect is similar to that done by all soft or unarmored scales.

Fig. 494. The cottony-cushion scale, *Icerya purchasi* Maskell.

The scale itself is rather large, red-brown, and covered with white or pale yellow, waxy filaments. White cottony egg masses with a fluted appearance are commonly seen and easily recognized so that other descriptive features of the scale are unimportant (Fig. 494). These masses are nearly $\frac{1}{2}$ inch in length and may contain up to 1000 bright red eggs. Hatching occurs in a period of a few days to nearly two months depending on the temperature, the red nymphs begin to feed, soon becoming covered with waxy cottony filaments and powder. The small delicate two-winged fly-like male scales are rarely seen.

Within twenty years after its introduction this scale was seriously threatening the citrus industry of California and no means of control was available. A search was made in Australia for the natural enemies that held it in check there. The vedalia lady beetle, *Rodolia cardinalis* (Muls.), was the

species found to be effective as a predator. Within eighteen months after the introduction of the vedalia into California citrus groves the infestation of cottony-cushion scale was reduced to the level of an occasional pest of minor importance. The predator has also been established in Florida and in other areas where needed. This is one of the classic examples of biological control of a destructive insect species.

Where chemical control measures are required use parathion or malathion.

BROWN SOFT SCALE

Coccus hesperidum L., Family Coccidae

Commonly known as soft brown scale, this unarmored species occurs outdoors throughout the world in tropical and subtropical areas, and is also known universally as a greenhouse pest. Like most of the scales that attack citrus, it has a wide range of additional host plants. On citrus it is often attended by ants, and control of the ants helps to reduce the scale population.

The adult female is brown, oval, flattened, and may be nearly 4 millimeters in length. Females lay only a few eggs at a time which hatch quickly and are therefore rarely seen. Reproduction is parthenogenetic, no males having been observed. There are several overlapping generations each year in greenhouses and three to five in outdoor subtropical areas. Like all unarmored or soft scales this species does not lose the legs and antennae at the first molt as do the armored scales.

This scale is not a problem where its many hymenopterous parasites are present.

Brown soft scale is controlled with the same insecticides outlined for purple and black scales with the following exceptions. DDT and parathion are not considered effective; however, malathion and parathion mixtures have been satisfactory.

Reference: *Conn. Agr. Exp. Sta. Bul.* 578, 1954.

OTHER UNARMORED SCALES

Order Homoptera, Family Coccidae

Hemispherical Scale, *Saissetia coffeae* (Walker), is a common greenhouse species found living in the open in the warmer regions, occasionally attacking citrus. It is also a pest of many ornamental plants, ferns being a common host. Adult females are strongly convex, smooth shiny brown, and nearly 3 millimeters in diameter. There are two generations each year; males are not common. The damage, life cycle, and control are the same as for black scale.

Nigra Scale, *Saissetia nigra* (Nietner), is found in greenhouses and out-

doors in tropical areas. Besides citrus it attacks other fruit crops, as well as ornamental plants, ivy, holly, and Japanese aralia being favored. Adult females are elliptical, flattened, and shiny black. The life cycle and control measures are the same as for black scale.

Tessellated Scale, *Eucalymnatus tessellatus* (Signoret), is found almost entirely in greenhouses on various tropical plants. Females are elliptical and flattened, green-black with a network of pale lines. They are oviparous, but the nymphs emerge from the eggs immediately after they are deposited. Control is the same as for other soft scales.

CITRUS WHITEFLY

***Dialeurodes citri* (Ashmead), Family Aleyrodidae**

Although the infestation in California was reported eradicated in 1942, this insect is still an important citrus pest in Florida and occasionally becomes destructive in other Gulf Coast states. Injury results directly from loss of plant sap, and indirectly from the sooty fungus growth that develops on the copious honeydew excretions of the whiteflies. The fungus often covers both foliage and fruits, retarding growth and reducing the market value of the fruits.

The lemon-yellow eggs are elliptical, 0.25 millimeters in length, and attached to the leaf by a short stalk. Hatching takes place in a week or more depending on the temperature, and the tiny, pale green nymphs migrate over the plant, insert their mouthparts and suck sap. After the first molt the legs and antennae are shed, and the nymphs resemble young soft scales. The last instar is thicker-bodied and is sometimes called a pupa. Nymphal development is completed in three to four weeks, and the four-winged adults, scarcely 1.6 millimeters in length, begin emerging. The wings, legs, and antennae are milk white, the body is pale yellow, and the eyes black. When at rest the wings are held roof-like over the body (Fig. 495). Development from egg to adult requires nearly fifty or more days depending on the temperature. There are usually three generations per year in Florida.

Natural control results from the presence of several species of entomophagous fungi. Some important species are the red fungus, *Aschersonia aleyrodis* Webber, and the brown fungus, *Aegerita webberi* Fawcett. These fungi are now generally present in all citrus groves and will increase in numbers when the proper environmental conditions prevail.

Spraying in late September or early October with 1 to 2% oil emulsion controls this pest on citrus. Parathion sprays are also satisfactory if they contain 1 to 2 pounds of 15% wettable powder in 100 gallons of water. DDT kills adults if 2 pounds of 50% wettable powder are used in 100 gallons of water. A repeat application is usually needed about ten days later

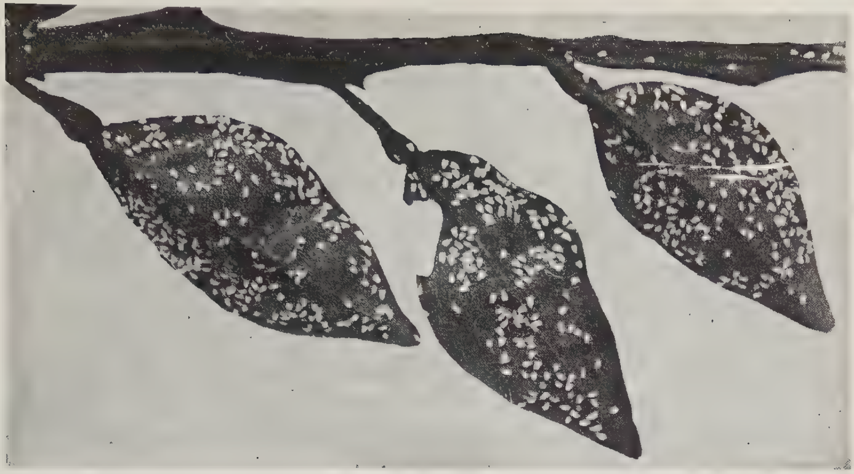


Fig. 495. The citrus whitefly, *Dialeurodes citri* (Ashmead); adult flies on foliage. (Morrill and Back, U.S.D.A.)

to eliminate an infestation. Emulsifiable concentrates of DDT give some control of the nymphs because of the oil they contain. In greenhouses, parathion, malathion, TEPP, endosulfan, and DDT have given good control of whitefly.

OTHER WHITEFLIES

Order Homoptera, Family Aleyrodidae

Cloudy-Winged Whitefly, *Dialeurodes citrifolii* (Morgan), resembles the citrus whitefly but lays black eggs and has a darkened or cloudy area on each wing; also, events in the life cycle are about two weeks later. This species has nearly the same distribution and is usually of lesser importance; in some areas of Florida, however, it appears to be on the increase. The yellow fungus, *Aschersonia goldiana* (S. and E.), attacks only this species, and, along with *Aegerita webberi* Fawcett, it brings about some natural control. Chemical control measures are the same as those for the citrus whitefly but the spray dates are usually two weeks later.

Woolly Whitefly, *Aleurothrixus floccosus* (Maskell), was first observed as a Florida citrus pest in 1909. It has never become important, apparently because its natural enemies have held it in check. The common name refers to the woolly waxy filaments that cover the last nymphal instar or pupa. The eggs are brown and slightly curved, resembling a tiny wiener. Adults are sluggish and have more yellow coloration in the body and wings than the cloudy-winged species.

Citrus Blackfly, *Aleurocanthus woglumi* Ashby, occurs in India, the

Philippine Islands and Ceylon, and in 1935 it was found in Mexico and the West Indies, where it is considered to be a serious citrus pest. All infestations in the United States have been eradicated. The adults have a slaty-blue appearance. They lay their tiny eggs largely in a spiral path on the undersides of the leaves. The eggs are creamy white at first, becoming almost black before hatching. They are attached to the leaf by a short stalk. There are three to six overlapping generations per year. Parasites introduced from India have shown promise as biological control agents; *Prospaltella opulenta* Silvestri is the most promising species. Eradication treatment consists of spray applications of 1.6% light medium emulsive oil combined with rotenone.

Avocado Whitefly, *Trialeurodes floridensis* (Quaintance), is occasionally found on citrus; it commonly attacks avocados and guavas in Florida. It resembles the citrus and greenhouse whiteflies in appearance and life cycle. Control measures are the same as those for the citrus whitefly.

CITRUS MEALYBUG

Planococcus citri (Risso), Family Pseudococcidae

Of the several species of mealybugs found on citrus in Florida, this one is considered to be most important. It is found out-of-doors in the South

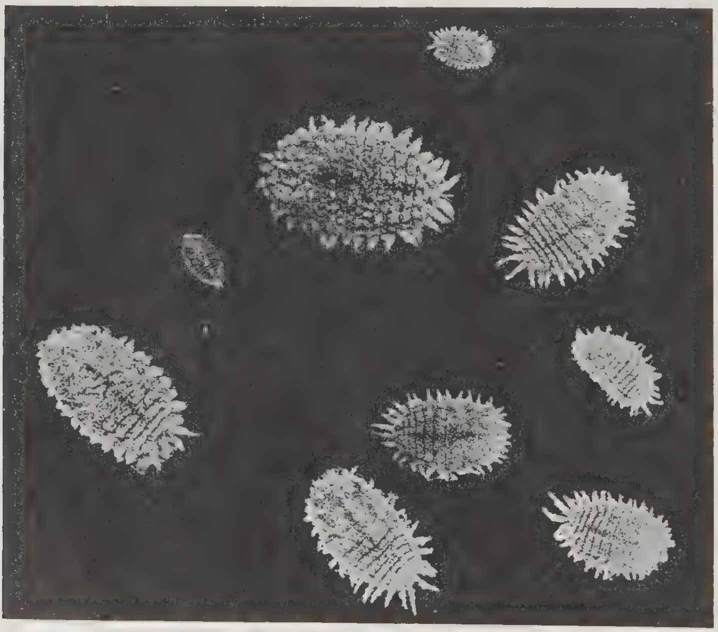


Fig. 496. The citrus mealybug, *Planococcus citri* (Risso); various stages of growth are shown. (Woglum and Neuls, U.S.D.A.)

Fig. 497. A lemon infested with the citrus mealybug. (Woglum and Neuls, U.S.D.A.)

and in greenhouses all over the country. It attacks primarily citrus and ornamental greenhouse plants but may occasionally occur on other hosts. Injury resulting from the feeding by these piercing-sucking insects consists primarily of reduced plant vigor because of sap loss, and the sooty fungus growth that develops on the honeydew excretions, which contaminate fruits and disfigure foliage.

Breeding is continuous in greenhouses and out-of-doors in tropical areas. There is very little winter survival of mealybugs outside greenhouses in the North. Adult females are oval, flattened, light brown insects with short spines projecting from the body margin and posterior end of the abdomen. Large specimens are 3 to 4 millimeters in body length. Their bodies are covered with a waxy or mealy powder from which they take their common name (Figs. 496 and 497).

Yellow eggs are produced in a cottony mass of waxy filaments which covers most of the female at the time of egg-laying. Each female may deposit over 500 eggs during her life span. Hatching takes place in a week or more depending on the temperature and the tiny yellow nymphs, resembling crawler scales, migrate over the plant and soon begin sucking sap. There are two or three overlapping generations per year out-of-doors and sometimes more in greenhouses. Immature males and females are similar, but after four weeks of nymphal development the males form a mass of silken filaments in which transformation to a gnat-like two-winged adult occurs nearly two weeks later. Upon mating the males soon die.

There is a high degree of natural control of mealybugs. Important predators include the brown lacewing, *Sympherobius angustatus* Banks, several species of lady beetles, of which *Cryptolaemus montrouzieri* (Muls.) (Fig. 498) is considered important, some chrysopids, syrphid fly larvae, and larvae of other true flies (Fig. 499). The important parasite species is the encyrtid, *Leptomastidea abnormis* (Gir.).

Fig. 498. *Cryptolaemus montrouzieri* (Muls.), a lady beetle predator of mealybugs. (Woglum and Borden, U.S.D.A.)

Fig. 499. *Leucopis atrifacies* Aldrich, a predator of mealybugs. (U.S.D.A.)

Control of Argentine and other species of attendant ants with chlordane, aldrin, heptachlor, or dieldrin also contributes to mealybug control.

This mealybug is normally controlled by oil emulsion or parathion and malathion sprays as recommended for scale insects. In greenhouses, aerosols or sprays of parathion, malathion, trithion, TEPP, or sulfotepp, have given satisfactory control.

Reference: *Calif. Agr. Exp. Sta. Bul.* 713, 1949.

OTHER MEALYBUGS

Order Homoptera, Family Pseudococcidae

Citrophilus Mealybug, *Pseudococcus fragilis* Brain, was found in California in 1913. It may be distinguished from *P. citri* by its anal filaments, of which a pair are nearly half as long as the body, and by four rows of thinly waxed depressions down the back, the middle pair being most conspicuous. There is no marked difference in the appearance or biology of this species and *P. citri*. A large number of host plants are attacked. Control out-of-doors has been secured largely by the encouragement of parasite and predator populations. In addition to the natural enemies listed for *P. citri*, two parasites from Australia have now reduced the populations of this mealybug to a level approaching complete control. These chalcid parasites are *Coccophagus gurneyi* Compere and *Tetracnemus pretiosa* Timberlake. If necessary, this mealybug can be controlled with the same insecticides given for citrus mealybug.

Long-Tailed Mealybug, *Pseudococcus adonidum* (L.), occurs on a

wide range of hosts both inside and outside greenhouses. This species is slightly smaller, the body is thinly covered with white wax, and a broad, faint dark stripe is evident on the back. Filaments along the sides are about $\frac{1}{2}$ the body width, and the terminal pair are as long as, or longer than, the body. No eggs are laid, the females giving birth to their young. In addition to the natural enemies given for the other species of mealybugs, this species is effectively checked by *Anarhopus sydneyensis* Timberlake, a parasite imported from Australia. Chemical control is the same as that given for citrus mealybug.

CITRUS THRIPS

Scirtothrips citri (Moulton), Family Thripidae

Citrus thrips are prevalent in most citrus regions of California, Arizona, and Texas. Oranges, lemons, nectarines, and grapefruits are commonly attacked, and there are other alternate hosts. Damage is caused by both nymphs and adults rasping the surface of foliage and fruits and sucking the cell contents. This stunts growth and produces a scabby or scurfy appearance of fruits. Buds are often killed, and new leaves are dwarfed, distorted, and of a characteristic gray appearance.

Citrus thrips overwinter as tiny bean-shaped eggs deposited during the autumn in the tissues of leaves and stems. Hatching occurs generally by early March and the pale wingless nymphs with red eyes begin feeding. As they increase in size they become yellow to orange, the eyes dull red. After the second instar growth is completed, the nymphs drop to the ground and transform to a prepupal or third instar and later a pupal or fourth instar before emerging as adults. The adults have four wings fringed with hair and carry them folded down the back (Fig. 500). They are pale orange-yellow and scarcely 2 mm. in length; the females are larger-bodied. Females can reproduce without mating, but then the progeny are all males. Development from egg to adult requires a month in cool weather

Fig. 500. The citrus thrips, *Scirtothrips citri* (Moulton), and the Florida flower thrips, *Frankliniella cephalica* (Crawford). (Courtesy of U.S.D.A. and Fla. Agr. Exp. Sta.)

and about two weeks in hot weather. There are probably ten or twelve generations per year in warmer localities.

Other species that may attack citrus are orchid thrips, *Chaetoanaphothrips orchidii* (Moulton), greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), western flower thrips, *Frankliniella occidentalis* (Pergande), and Florida flower thrips, *Frankliniella cephalica* (Crawford) (Fig. 500). They are all similar to citrus thrips in appearance and life cycle, but they are more often present in the blossoms and this feeding has been considered less important.

Natural control by predatory thrips, lady beetles, mites, and spiders has been observed but has not been especially valuable in checking a destructive thrips population.

Control is accomplished by treating with one of the following insecticides: sulfur dust, DDT-sulfur dust, sabadilla, dieldrin, DDT, tartar emetic, parathion, or dioxathion. Applications should be made at petal fall to prevent scarring and during the summer to protect new growth. DDT is not advised where there is a trace of cottony-cushion scale because of killing its predator, *Rodolia cardinalis* (Mulsant). Tartar emetic is effective in areas where resistant strains of thrips have not developed.

References: *U.S.D.A. Cir.* 708, 1944; *J. Econ. Ent.*, 45:578–593, 1952; *Calif. Citrus Exp. Sta. Pest Cont. Guide*, 1965.

CITRUS RED MITE

Panonychus citri (McGregor), Family Tetranychidae

This mite is known as the purple mite in Florida and as the citrus red spider in California. Although found in many of the Gulf Coast states, the citrus red mite has been considered a major pest only in Florida and California. Both nymphs and adults extract the sap from foliage, fruits, and tender branches with their piercing-sucking mouthparts, producing tiny gray or silvery spots on the leaves and fruits. When leaf damage is severe, the normal photosynthetic processes of the plant are greatly inhibited, resulting in leaf drop, decreased plant vigor, and smaller, poorer quality fruits.

This mite closely resembles the European red mite, which is a major pest of deciduous trees in the North. The bright red eggs are spherical but slightly flattened, with a dorsal hair-like projection. In warm weather, hatching occurs in a week or more and the tiny six-legged nymphs (often called larvae) migrate over the plant and begin feeding. After the first molt all the succeeding stages, called protonymphs, deutonymphs, and adults, have eight legs. The adult female is dark velvety red, often with a tinge of purple, globular, with prominent, dorsal, white bristles arising from tubercles on the body (Fig. 501). The adult male is smaller with a more pointed

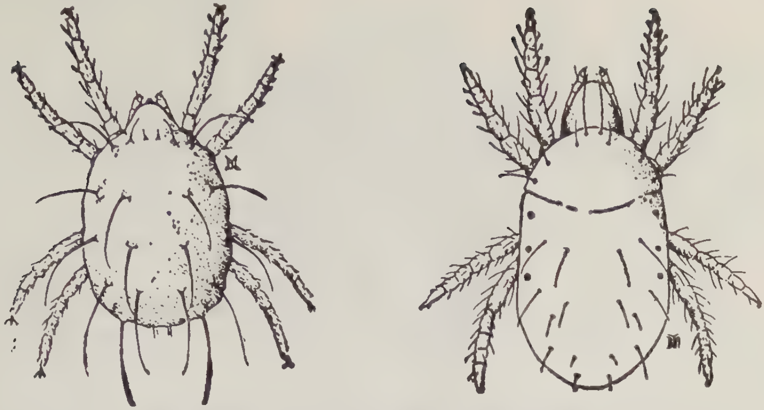


Fig. 501. Citrus mites: the citrus red mite, *Panonychus citri* (McGregor), (left); the six-spotted mite, *Eotetranychus sexmaculatus* (Riley), (right). (Quayle, Calif. Agr. Exp. Sta.)

abdomen. Development from egg to adult requires less than three weeks, and twelve to fifteen generations may occur annually. Unfertilized eggs develop only into males.

Various species of typhlodromid mites are important as predators of this and other mite species.

Recommended chemicals for controlling citrus red mite are mineral oil emulsions, ovex, tetradifon, Kelthane, dioxathion, trithion, chlorobenzilate, DN 111, and organophosphorus compounds, if mites have not developed resistance to them. Adult mites are not killed by ovex and tetradifon. If adult mites are abundant, it may be advisable to add chlorobenzilate or DN 111 to the spray mixture. DN compounds have been used with success but they are apt to be phytotoxic when temperatures 85° F. or higher follow treatments. Oil emulsions sprays for controlling scale insects will also check populations of this mite.

References: *J. Econ. Ent.*, 46:1014, 1953; 47:356–357, 1954; 54:55–60, 1961; *U.S.D.A. Agr. Handbook* 290, 1965.

CITRUS RUST MITE

Phyllocoptruta oleivora (Ashmead), Family Eriophyidae

This mite is one of the most common and serious pests of citrus in Florida, Texas, and other Gulf Coast states as well as in some citrus districts in California. The mites feed on the sap of leaves, twigs, and fruits of all kinds of citrus; lemon, lime, grapefruit, and orange are most severely damaged. Leaves lose their glossy appearance, becoming bronzed and stunted under heavy infestations, often dropping prematurely. New

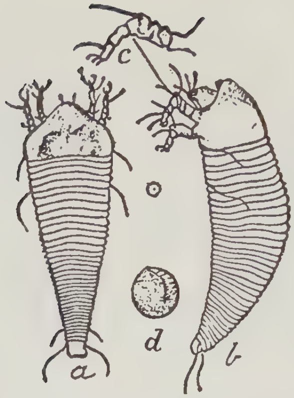


Fig. 502. The citrus rust mite, *Phyllocoptruta oleivora* (Ashmead): *a,* dorsal view; *b,* lateral view enlarged, the dot in circle indicating natural size; *c,* leg; *d,* egg with embryo just about ready to hatch, more enlarged. (Hubbard, U.S.D.A.)

twig growth is stunted and discolored. Damaged fruits become light brown to black in the areas where the mites feed. This discoloration is called russeting and accounts for great losses every year owing to reduced size, quality, and poor appearance of the fruits.

Citrus mites are very small, averaging 0.1 mm. in length. They are lemon-yellow, elongate, tapering posteriorly, with two pairs of legs (Fig. 502). Only females have been found. Pale yellow spherical eggs are commonly deposited on fruits and foliage. Hatching takes place in two or more days and the young develop to maturity in seven to ten days in summer. Many overlapping generations occur throughout the year but the mites are less abundant in winter and in July and early August.

Excellent control can be obtained using sulfur as a dust or spray. Dusts are more easily applied but more applications are needed because they are quickly washed away by rains. Other control chemicals are Zineb, chlorobenzilate, dioxathion, trithion, and ethion (not on limes). Applications should be made as needed. Follow the specific recommendations for your citrus area. Weekly examination of the leaves and fruits with a hand magnifier to determine whether mites are present is of help in deciding need for treatment.

References: *U.S.D.A. Tech. Bul.* 176, 1930; *Farmers' Bul.* 2012, 1950; *Agr. Handbook* 290, 1965; *Calif. Citrus Exp. Sta. Pest Cont. Guide,* 1965.

OTHER MITE SPECIES

Six-Spotted Spider Mite, *Eotetranychus sexmaculatus* (Riley), is occasionally a pest in many citrus-growing areas. It resembles the two-spotted spider mite in general appearance, life cycle, and habits. However, the eggs bear a filamentous stalk like the citrus red mite, and the females have six pigmented dorsal spots which suggest the common name. These spots are not always conspicuous and they may sometimes be absent (Fig. 501). The same miticides used for citrus red mite will control this species.

Citrus Flat Mite, *Brevipalpus lewisi* McGregor, is present as a pest in a few counties in California and Arizona. It is said to attack only the fruits and only when the color begins to appear in them. Their feeding causes oranges to become russeted and lemons to appear silvery. The egg has a central filamentous stalk and the adult is amber with some spots on the lateral margins of the body. Webbing is produced by this mite Controls suggested are the same as for the important mite species.

Texas Citrus Mite, *Eutetranychus banksi* Pritchard & Baker, at times is an important species in the Texas citrus belt and in Florida. It forms little webbing, feeds on the upper leaf surface, and is more rapid in its movements than the citrus red mite which it closely resembles in appearance and life cycle. The same miticides recommended for citrus red mite will control this species.

Citrus Bud Mite, *Aceria sheldoni* (Ewing), is a world-wide pest, but in the United States it is found principally along the coastal areas of California, Florida, and the Hawaiian Islands, where it attacks all kinds of citrus and is most damaging to lemons. It feeds primarily in the buds which may be killed or may cause the growth of twigs, leaves, blossoms, and fruits to be stunted and malformed. This is an eriophyid mite and resembles the citrus rust mite in appearance and life history. Development from egg to adult is completed in ten or more days depending on the temperature. Control is accomplished with a 1.6 to 2% light-medium oil spray applied once or twice a year. Satisfactory results have also been obtained by sprays of chlorobenzilate alone or in combination with the oil emulsions.

References: *J. Econ. Ent.,* 44:823–832, 1951; 45:271–273, 1952; *U.S.D.A. Agr. Handbook* 290, 1965; *Calif. Citrus Exp. Sta. Pest Cont. Guide,* 1965.

SPIREA APHID

Aphis spiraecola Patch, Family Aphididae

Often called the citrus aphid because it is the most important species attacking that crop in both California and Florida, the spirea aphid is widely distributed elsewhere in the United States and was named for its common host, spirea. In addition to citrus and spirea it feeds on apple,

pear, quince, and haw. This species is closely related to the apple aphid, *A. pomi,* with which it has often been confused. Injury consists of removal of plant sap by the piercing-sucking nymphs and adults which results in curled, stunted, or distorted foliage and fruits. Also, under heavy infestation, the large amounts of excreted honeydew serve as a medium for sooty fungus growth that smudges the fruits and leaves. Newly planted trees are said to suffer the greatest injury.

In the more southern citrus areas, this typically green aphid produces only parthenogenetic ovoviviparous generations throughout the year; from approximately Gainesville, Florida, northward sexual forms are produced in the fall which deposit the overwintering eggs on spirea. In the South the life cycle may be completed in six days. Since it probably does not average more than ten to twelve days, many generations are produced each year. Heavy populations may be observed on the tender growing tips of spirea in the spring. Ants are often associated with this aphid.

Natural control results from numerous species of lady beetles, aphid lions, syrphid fly larvae, and the parasite, *Aphidius testaceipes* (Cresson).

Effective insecticides include malathion, TEPP, rotenone emulsifiable, nicotine sulfate, rotenone plus mineral oil, mevinphos, and demeton. Treatments should be made when the infestation warrants them; this is usually in the spring.

MEDITERRANEAN FRUIT FLY

***Ceratitis capitata* (Wiedemann), Family Tephritidae**

The Mediterranean fruit fly has long been known as one of the most destructive insects attacking citrus and other fruits in many subtropical areas of the world except North America. Quarantines have been maintained to keep it out of the United States. In spite of these precautions, the fly was discovered in Florida in 1929. Prompt action was taken by state and federal authorities, and through their combined efforts the fly was exterminated in less than a year. This fly was again discovered in the vicinity of Miami, Florida, in 1956; this infestation has also been eradicated.

The fruit fly is somewhat smaller than the house fly, yellow-and-black-bodied, with transparent wings having darker-banded areas (Fig. 503). The nearly white larva is a tapered legless maggot almost $\frac{3}{8}$ inch in length. The eggs are laid in the skin of the fruits and the larvae feed inside. When their development is completed they drop to the ground, enter the soil, and change to brown puparia. Development from egg to adult may occur in less than three weeks, but it may require three months or more under unfavorable conditions. There are usually several generations per year depending on the locality. Winter is passed as puparia in the

Fig. 503. Development of the Mediterranean fruit fly: adult, larva, puparium, and larva working in a peach. (Compere.)

soil, or as adults in cooler regions, or breeding may be continuous in warmer regions.

No control measures are needed in the United States owing to complete eradication of the infestation. In other countries promising results have been obtained with new chlorinated hydrocarbon- and phosphate-type insecticides applied to kill the adults before they lay eggs. Residual sprays, bait sprays, and soil poisons are of value in control and eradication programs.

Reference: *J. Econ. Ent.,* 45:274–279, 1952; 54:30–35, 1961.

MEXICAN FRUIT FLY

Anastrepha ludens (Loew), Family Tephritidae

The Mexican fruit fly has long been known as the orange maggot, but it attacks other citrus as well. Native to Mexico, it has also been found in the Rio Grande Valley in Texas. Quarantines are maintained to prevent its spread from these areas and to prevent additional infestation from Mexico. It should be mentioned that the authorities of Mexico cooperate in the enforcement of the necessary quarantines and control programs. Efforts are made to exterminate the fruit fly wherever it has become established.

The yellow-brown adult is larger than the house fly. The wings are transparent except where mottled with brown areas. Females have an elongated tip on the abdomen which encloses the ovipositor (Fig. 504). The green eggs are deposited just beneath the skin of the fruit; the lar-

Fig. 504. The Mexican fruit fly, *Anastrepha ludens* (Loew). (Riley.)

vae are creamy white legless maggots with a tapered body. Damage is caused by the maggot working in the fruit. There are four to six generations a year.

All fruits shipped from the infested area are fumigated. The continuance of these efforts in extermination and the maintenance of quarantine regulations are therefore of vital interest to both producers and consumers of citrus fruits.

References: *U.S.D.A. PA–265*, 1964; *Misc. Pub.* 531, 1944.

ORANGE CATERPILLARS

Order Lepidoptera

Foliage and fruits of citrus are sometimes attacked by various species of caterpillars.

The "orange dogs" are larvae of swallowtail butterflies. *Papilio zelicaon* Lucas is the common species in California, whereas the giant swallowtail,

Fig. 505. The "orange dog" or larva of the giant swallowtail butterfly, *Papilio cresphontes* Cramer.

P. cresphontes Cramer (Fig. 505), is more prevalent in Florida and the Gulf States.

One of the pests of deciduous fruit trees has become of some importance as a pest of citrus trees in California. This is the fruit-tree leaf roller, *Archips argyrospilus* (Walker) (see. p. 449).

Orangeworms of several species have been recorded in California. The larvae of one of these, the orange tortrix, *Argyrotaenia citrana* (Fernald), feed on tender foliage and also enter fruits. Resembling the orange tortrix is another species called the garden tortrix, *Clepsis peritana* (Clemens). The pink scavenger caterpillar, *Pyroderces rileyi* (Walsingham), feeds primarily on fruits that are injured by other insects, but it occasionally attacks sound fruits. Other occasional pests are the navel orangeworm, *Paramyelois transitella* (Walker), the omnivorous leaf roller, *Platynota stultana* Walsingham (see p. 229), the western tussock moth, *Hemerocampa vetusta* (Boisduval), and the cutworms, *Xylomyges curialis* Grote, *Peridroma saucia* (Hübner), and *Heliothis phloxiphaga* Grote.

Control of these pests is usually accomplished by the regular sprays for more important citrus pests. However, special treatments are sometimes required and the following chemicals have been effective in killing these pests: carbaryl, cryolite, DDT, TDE, parathion, guthion, and mevinphos.

References: *Hilgardia,* 31:129–171, 1961; *Calif. Agr. Exp. Sta. Bul.* 764, 1958; *Calif. Agr.* 18:10–12, 1964; *Calif. Citrus Exp. Sta. Pest Cont. Guide,* 1965.

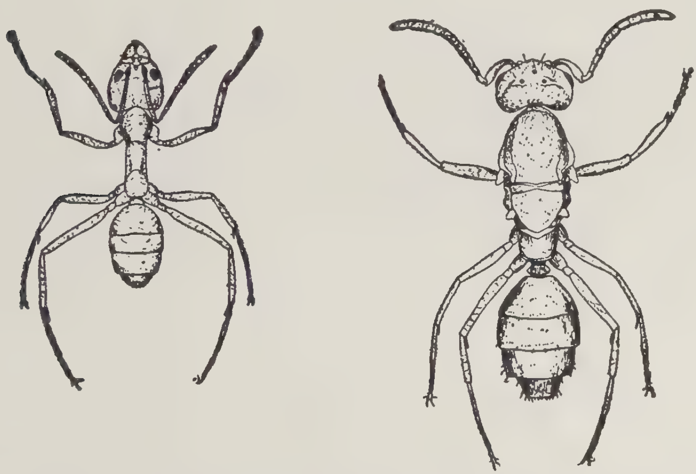


Fig. 506. The Argentine ant, *Iridomyrmex humilis* (Mayr): (left) worker; (right) wingless queen. (Newell.)

ARGENTINE ANT

Iridomyrmex humilis (Mayr), Family Formicidae

The Argentine ant is a South American insect introduced in New Orleans about 1890. Since that time it has become established in the southern states, particularly the lower Mississippi Valley and in California. It is apparently unable to survive except where the winters are warm.

This ant is important in citrus groves because of its relations with aphids, scales, and mealybugs. It is attracted to these insects because of the honeydew they produce and it may carry them from place to place thus furthering their spread. It readily seeks colonies of *Coccus hesperidum* L.; apparently the honeydew of this species is especially attractive. The ant transports rusty plum aphids to sugarcane, thus aiding in the transmission and spread of mosaic. It is also detrimental because it destroys both eggs and active forms of predators and parasites. Observations indicate that, where the ants are absent from the citrus groves, natural control of mealybugs and other pests is greater.

The worker ants in this species are exceedingly small, usually less than 2 mm. long; the queens may attain a length of 6 mm. (Fig. 506). Their color is dark brown, the antennae are elbowed, the basal portion being much longer in the worker caste of these ants than in other species. Nests are made in the soil of orchards, fields, and gardens.

Effective control can be accomplished by locating the nests and treating them with dusts of 2.5% heptachlor, aldrin, dieldrin, or endrin, or 5% chlordane. Apply with a hand dust gun. Sprays, dusts, or granular formulations of the same materials may be applied to the soil over large areas at dosages of 1 to 2 pounds of actual chemical per acre. This treatment is more effective, since it includes the places where the ants forage, as well as the nests. In citrus groves, direct the insecticide to the region under the tree, particularly next to the trunk. Avoid getting the toxicants on the fruits. One treatment should last an entire season.

References: *J. Econ. Ent.*, 47:591–593, 1954; *Ann. Ent. Soc. Amer.* 49:441–447, 1956.

22

Insects Injurious to Stored Products and Household Goods

Insects destroy at least 5% of the world production of all cereal grains after they are harvested and while they are in storage on the farm, in elevators, or in warehouses. These losses consist of lowered weight and food value, insect adulteration, heating of grains with resultant mold and spoilage, and low germination of seeds. The actual amount of grain loss annually has been estimated at 300 million bushels.

Processed and packaged foods are also subject to attack, and, unless frequent examinations are made and control measures initiated, serious damage may result in processing plants, wholesale warehouses, retail stores, and homes.

Loss of clothing, rugs, furniture, and other household furnishings, because of clothes moths, carpet beetles, and similar pests has been estimated at $200 million to $500 million annually.

Only the most important pests can be discussed in this chapter, and, since all insects of stored products are controlled in much the same way, these measures are discussed after all the insects are described.

Since references on this subject include information about the insects as well as control, they are listed after the discussion on control.

GRANARY AND RICE WEEVILS

Order Coleoptera, Family Curculionidae

The granary weevil, *Sitophilus granarius* (L.), and the rice weevil, *Sitophilus oryzae* (L.), differ from each other only slightly. The rice weevil can fly, has round pits on the thorax, and is nearly black except for two faintly light spots on each elytron (Fig. 507). The granary weevil cannot fly, has oval pits on the thorax, and is uniformly dark brown or black.

Fig. 507. Larva and adult of the rice weevil, *Sitophilus oryzae* (L.). (U.S.D.A.)

The length of each beetle is approximately $\frac{1}{8}$ inch, and both have chewing mouthparts at the end of their snout or prolonged head. Both species may be found infesting stored grains all over the world. Grains on farms, in transit, or in elevators are subject to attack. In the South, the rice weevil also attacks grain in the field.

Each female may live several months and deposit 200 to 400 eggs during that period. Before oviposition, she bores a small hole into the grain with her mouthparts, deposits the egg in this cavity, and covers it with a gelatinous fluid. After hatching, the small, white, fleshy, legless larvae devour the inside portion of the grains and, when fully developed, transform to pupae, and emerge as adults. Although the life cycle may be completed in four weeks, this period is greatly prolonged by cool weather. The entire larval and pupal periods are spent inside whole grains. These insects are favored by grains with a high moisture content.

CONFUSED AND RED FLOUR BEETLES

Order Coleoptera, Family Tenebrionidae

The confused flour beetle, *Tribolium confusum* duVal, and the red flour beetle, *Tribolium castaneum* (Herbst), are found throughout the world attacking primarily milled-grain products. In whole grains they feed only on grain dust and broken kernels. The confused flour beetle is undoubtedly the most abundant and injurious insect pest of flour mills in the United States. In temperate regions the confused species predominates; the red species is more subtropical.

The two species are very similar (Fig. 508); both are about 4 mm. in length and reddish brown. The head and dorsal sides of the thorax are densely covered with minute punctures. The easiest distinguishing character is that the segments of the antennae of the confused flour beetle increase in size gradually from the base to the tip, whereas in the red flour beetle the last few segments are abruptly much larger than the preceding ones.

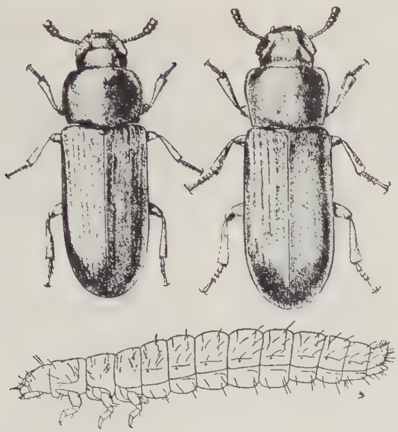


Fig. 508. The red flour beetle, *Tribolium castaneum* (Herbst) (left), and the confused flour beetle, *T. confusum* du Val (right). Below, larva of *T. castaneum.* (U.S.D.A.)

The average life span of the beetles is around one year. Each female lays 400 to 500 white eggs in flour or other foods which hatch in a week or more into slender, cylindrical, white larvae tinged with yellow. When fully grown they transform to naked pupae, and a week later adult emergence takes place. The period from egg to adult requires about four weeks in warm habitats. Development is retarded by cool temperatures and unfavorable food.

SAW-TOOTHED GRAIN BEETLE

Oryzaephilus surinamensis **(L.), Family Cucujidae**

The saw-toothed grain beetle is the most prevalent of the beetles in stored foods. It is a cosmopolitan species, and its origin is not definitely established.

This red-brown beetle is one of the smallest of the grain pests, being not more than 3 mm. long, and of slender, flattened form (Fig. 509). Edges of the prothorax are distinctly serrated. The slender larva is whitish with some brown on the head and margins of the segments; it has well-developed legs.

Breeding is continuous when temperatures permit, and all life stages may be found together in infestations, both larvae and adults feeding on the products. The adults live, on the average, from six to ten months; some individuals may live as long as three years. Each female deposits 40 to 280 white eggs, which hatch in a few days. When larval develop-

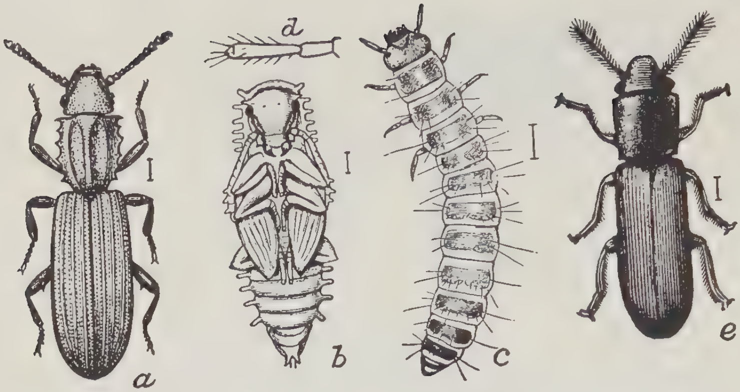


Fig. 509. Grain beetles. (Left) the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.): *a,* adult; *b,* pupa; *c,* larva; *d,* antenna; *e,* the square-necked grain beetle, *Cathartus quadricollis* (Guér.). (U.S.D.A.)

ment is completed they pupate within delicate cocoon-like coverings made of food particles held together with a sticky secretion. After a week the adults emerge, completing the cycle, which may take three to four weeks at summer temperatures.

SQUARE-NECKED GRAIN BEETLE

***Cathartus quadricollis* (Guér.), Family Cucujidae**

Similar to the saw-toothed species, the square-necked grain beetle is a trifle larger, darker in color, and lacks the serrations on the prothorax (Fig. 509). This beetle is chiefly abundant in the South, where it is found in great numbers infesting seed pods of various plants. Stored corn as well as exposed ears in the field are attacked. The life cycle is very similar to that of the saw-toothed grain beetle.

ANGOUMOIS GRAIN MOTH

***Sitotroga cerealella* (Olivier), Family Gelechiidae**

The most common of the moths infesting whole grains is the angoumois grain moth. World-wide in distribution, the larvae attack grains both in storage and in the field, and are especially destructive in southern United States.

The larval stage overwinters in the North; in the South breeding is continuous throughout the year, retarded when the temperature is low and accelerated when it is high. Heated buildings such as mills and warehouses provide ideal conditions for development in areas of cold weather.

The small buff moths with narrow wings fringed with hairs (Fig. 510),

Fig. 510. The angoumois grain moth, *Sitotroga cerealella* (Olivier). (King, Pa. Dept. Agr.)

emerge in the spring and either lay their white eggs on stored grains or fly to fields and deposit them on developing heads of small grains. The average number deposited by each female is forty, but some are known to lay almost 400. The eggs change to red as they age. Upon hatching the tiny white larvae chew into the grains and devour the inside portion. Before pupation each larva prepares an exit through the seed coat by cutting the surface approximately three-fourths the circumference of a circle, leaving a weakly fastened flap which the adult moth pushes out of the way to effect emergence. Damaged ears of corn have the appearance shown in Fig. 511. Development from egg to adult may be completed in five weeks in warm areas; it is prolonged by lower temperatures.

INDIAN MEAL MOTH

Plodia interpunctella (Hübner), Family Pyralidae

A native of Europe but now found world-wide, this insect is considered the most troublesome of the grain-infesting moths. Damage is caused by the larvae spinning silken threads as they feed and crawl, thus webbing the particles of food together. Besides infesting all cereal products and whole grains (Fig. 512), this species also feeds on a wide variety of foods, such as dried fruits, nuts, dog biscuits, dried milk, and seeds.

The moth has a wing expanse of nearly $\frac{3}{4}$ inch, the apical portion of the fore wings being red-brown or coppery and the basal portion gray (Fig. 513). Each female deposits 100 to 300 gray-white eggs, singly or in groups, on food materials. When fully grown the brown-headed larvae are nearly half an inch long, white-bodied tinged with pink. They spin silken cocoons, in which transformation to pupae occurs, and later emerge as adults. The entire life cycle requires four to six weeks during the summer.

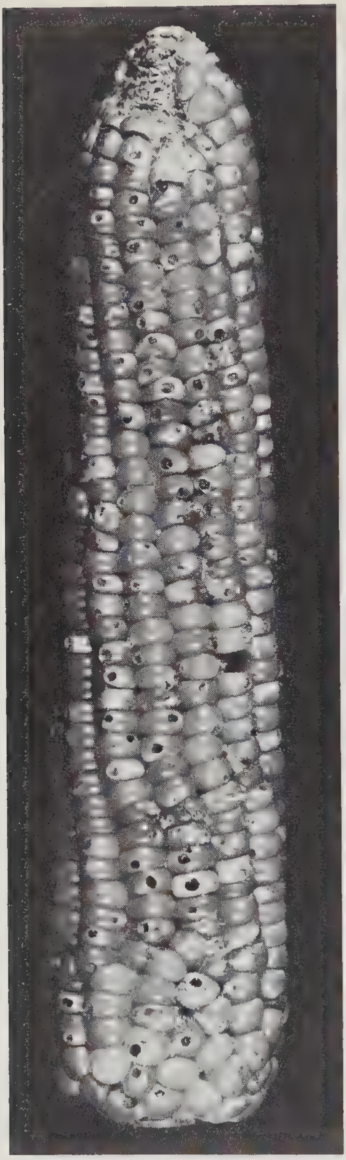


Fig. 511. Larval damage to popcorn by the angoumois grain moth. (Original.)

Fig. 512. Work of the Indian meal moth showing the characteristic webbing by the larvae. (Back and Cotton, U.S.D.A.)

Fig. 513. (Left) the meal moth, *Pyralis farinalis* (L.); (right) and the Indian meal moth, *Plodia interpunctella* (Hübner). (U.S.D.A.)

MEDITERRANEAN FLOUR MOTH

Anagasta kuehniella (Zeller), Family Pyralidae

The Mediterranean flour moth is a native of Europe and was discovered in California in 1892. It has since spread throughout the United States and is considered most troublesome in flour mills. Slightly larger than the angoumois grain moth, this insect has a wing expanse of nearly an inch and is gray with darker markings on the fore wings (Fig. 514). The larvae spin silken threads wherever they crawl, webbing and matting together particles of food on which they feed. Although milled cereal grain products are most often infested, whole grains may also be damaged. In flour mills the machinery may become so clogged with matted flour that operations are halted. Infestations in homes usually can be traced to purchased infested cereal products.

The females lay tiny white eggs in flour, meal, or grains, which hatch in a few days into white larvae with brown heads. These feed, becoming pink-tinged as development proceeds, finally spinning silken cocoons in which pupation takes place. The adults emerge soon afterwards completing the cycle, which normally requires eight or nine weeks.

Three other members of this family occasionally are found in dried fruits, nuts, grains, cereal products, and tobacco but are not considered

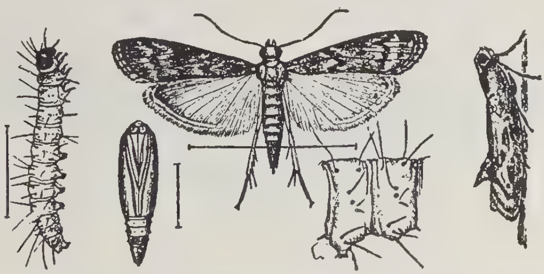


Fig. 514. The Mediterranean flour moth, *Anagasta küehniella* (Zeller). (U.S.D.A.)

major pests in the United States. They are the raisin or fig moth, *Cadra figuliella* (Gregson), the almond moth, *C. cautella* (Walker), and the tobacco moth, *Ephestia elutella* (Hübner).

MEAL MOTH

Pyralis farinalis (L.), Family Pyralidae

This insect has also been called the meal snout moth. It is larger than the Indian meal moth, having a wing expanse of about an inch. The fore wings are red-brown, each having two wavy transverse white bands (Fig. 513). Widely distributed, although less abundant, the meal moth is a general feeder in the larval stage, attacking milled grains but more likely to be abundant in damp, spoiled grains or grain products in poor condition. The bags of infested sacked feeds or grains may be cut by the larva, allowing the materials to sift out. Female moths deposit 200 to 400 eggs which hatch into whitish larvae with dark heads. They construct tubes of silk mixed with particles of food in which they feed from the openings at the end. When fully developed the larvae spin silken cocoons in which

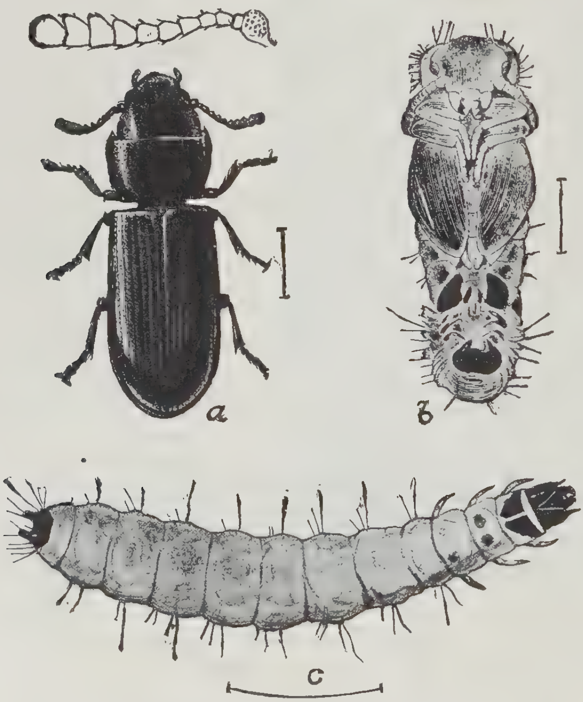


Fig. 515. The cadelle, *Tenebroides mauritanicus* (L.): *a*, adult beetle with enlarged antenna; *b*, pupa; *c*, larva. (U.S.D.A.)

pupation occurs, the adults emerging several days later. The developmental period requires six to eight weeks in warm weather.

CADELLE

Tenebroides mauritanicus (L.), Family Ostomatidae

This cosmopolitan insect, thought to be a native of America, is a shiny black, elongate beetle measuring $\frac{3}{8}$ inch (Fig. 515). The fleshy, white, elongated larva with a black head and thoracic shield, and two dark horny projections at the posterior end, is easily recognized. Both adults and larvae feed on cereal products and whole grains. They often devour only the germ, leaving the endosperm portion of grains. In mills they frequently damage the silk bolting cloth, and are known as "bolting cloth beetles."

Each female is capable of depositing almost 1000 eggs during her lifetime, which may extend over a period of one or two years. These white eggs are laid in masses in the food material and hatch in a week during warm weather. The larvae feed and frequently bore into the timbers of wooden bins. When fully developed they migrate to secluded places where transformation to pupae takes place, with adult emergence occurring soon afterward. The entire life cycle can be completed in seventy days during hot summer weather.

LESSER GRAIN BORER

Rhyzopertha dominica (F.), Family Bostrichidae

Although one of the smallest beetles attacking grain in this country, the lesser grain borer is one of the most destructive. Both adults and larvae cause serious damage to a wide variety of grains. This has been noted especially in the South, but infested samples have been found in all the large grain centers.

The beetle is easily recognized by its slender, cylindrical form, shiny brown or black color, roughened surface, and small size of less than $\frac{1}{8}$ inch. Each female lays 300 to 500 eggs, dropping them singly or in groups in loose grain. Hatching takes place in a few days and the white larvae feed on the flour produced by the feeding beetles, or they bore directly into grains, feeding until growth is complete. Pupation follows and in a short time the adults eat their way out. Development from egg to adult requires approximately one month at summer temperatures.

FLAT GRAIN BEETLE

Cryptolestes pusillus (Schönh.), Family Cucujidae

The flat grain beetle is about $\frac{1}{16}$ inch long, flattened, oblong, red-brown, with antennae almost $\frac{2}{3}$ as long as the body. It is world-wide in distribution and is often found associated with the rice weevil, apparently because

the adult is unable to survive in sound, uninjured grain. It frequently infests grains and cereal products in poor condition.

The tiny white eggs are dropped in farinaceous material. In whole grains, the larvae often devour only the germ. When development is complete they form cocoons, followed by pupation and adult emergence, the entire life cycle requiring five to nine weeks.

The rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), is similar to the flat grain beetle in habits and appearance; it differs in that the antennae of the males are not more than half as long as the body. Being more resistant to cold weather, it is more common in the northern states than related species.

MEALWORMS

Order Coleoptera, Family Tenebrionidae

The yellow mealworm, *Tenebrio molitor* L. (Fig. 516), and the dark mealworm, *Tenebrio obscurus* F., are the larvae of the largest beetles attacking grains and cereal products. The adults are nearly $\frac{3}{4}$ inch in length, shiny dark brown for the yellow species, and dull black for the

Fig. 516. The yellow mealworm, *Tenebrio molitor* L.; adult beetle, pupae, and larvae, with wheat grains to indicate size. (Back and Cotton, U.S.D.A.)

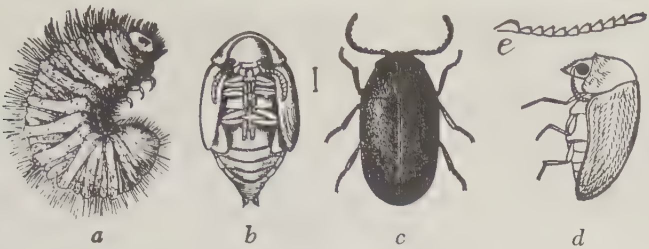


Fig. 517. The cigarette beetle, *Lasioderma serricorne* (F.), a pest of miscellaneous household materials: *a,* larva; *b,* pupa; *c,* adult; *d,* side view of adult; *e,* antenna; all greatly enlarged. (U.S.D.A.)

dark species. Larvae, when fully grown, are well over an inch long and are yellow or gray-brown, according to the species.

Both are seldom found in cereal products in homes but are often numerous in neglected grains and milled products that accumulate in dark corners, under sacks, in bins, or in places where livestock feeds are stored. Moist areas are their natural habitat.

The larval stage overwinters and adults appear in June, the females laying almost 500 bean-shaped white eggs. Hatching occurs in about two weeks, with larval development continuing throughout the summer followed by hibernation during the winter and transformation to pupae in late spring. There is only one generation each year.

Sanitation is often the simplest way to eliminate this insect.

CIGARETTE BEETLE

Lasioderma serricorne **(F.), FAMILY ANOBIIDAE**

The cigarette beetle is found in temperate, subtropical, and tropical areas attacking tobacco, seeds, spices, pepper, drugs, and occasionally grain and cereal products. It is a small, robust, oval, light brown beetle, with the head bent down sharply, giving a humped appearance when viewed from the side (Fig. 517). Although variable in size, it is usually about $\frac{1}{10}$ inch in length. The antennae are serrate.

The adults live two to four weeks, and during this time the females lay almost 100 white eggs which hatch into whitish, curved, hairy larvae. Pupation and adult emergence completes the life cycle, which requires about six weeks during the summer.

DRUG-STORE BEETLE

Stegobium paniceum **(L.), FAMILY ANOBIIDAE**

Very similar in appearance and life cycle to the cigarette beetle with which it is closely allied, the drug-store beetle differs primarily in being

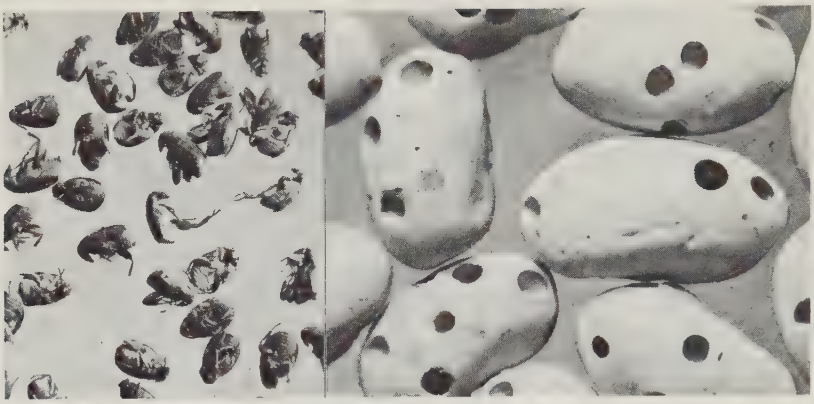


Fig. 518. Bean weevils and damaged beans.

more elongate, having distinctly striated wing covers, three slightly enlarged segments at the tip of the antennae, and a less hairy larval stage. It is a very general feeder, attacking many drugs, pepper, spices, seeds, and processed foods of all kinds.

PEA AND BEAN WEEVILS

Order Coleoptera, Family Bruchidae

Some species of beetles that are field pests of beans, peas, and cowpeas also attack the dried seeds of these crops in storage, often causing serious damage. An important species in this group is the bean weevil, *Acanthoscelides obtectus* (Say), which is widely distributed in the United States and causes damage as shown in Fig. 518. The broadbean weevil, *Bruchus rufimanus* Boheman, is found on the West Coast; the cowpea weevil, *Callosobruchus maculatus* (F.), and the southern cowpea weevil, *Bruchidius chinensis* (Thunberg), are more abundant in the South. All these species except the broadbean weevil can produce repeated generations in dried seeds in storage, provided that the temperature is favorable. The pea weevil, *Bruchus pisorum* (L.), is a pest of peas in the field and may complete its development in the seeds after the crop is harvested but does not attack dry peas in storage. Unless killed by fumigation or by other treatment, pea weevils may remain in hibernation within the container of seed throughout the winter. There is only one generation a year. More information on this group of insects is given under pests of leguminous crops.

CONTROL OF INSECT PESTS OF STORED GRAINS AND OTHER FOOD PRODUCTS

A control program for this group of pests is essentially the same for the home, farm, mill, elevator, or warehouse, the main difference being in

the scope of operations and the equipment used. With this in mind, the following are recommended procedures: provide clean storage, practice sanitation, use residual sprays, apply seed protectants, inspect frequently, fumigate, supercool and superheat. All these measures need not be taken in every situation.

Proper storage means clean, tight, dry bins or other easily accessible facilities, which not only afford protection from insects, rodents, birds, and poultry, and can be easily inspected or fumigated, but also provide reasonable safety from fire and wind damage. Clean, insect-free grains stored with a moisture content of 9% or less are seldom subject to attack. It is well to keep in mind that the factors favorable for preserving the keeping quality of grain and cereal products are generally unfavorable for the development of stored-grain insects.

Sanitation measures consist of thoroughly cleaning out old grain remnants from granaries, bins, or other places where these accumulations may serve as breeding areas. All infested materials should be fumigated, fed to livestock, or destroyed.

The wall and floor surfaces of thoroughly cleaned storage facilities should then be sprayed with residual insecticides of either 2% malathion, 2.5% methoxychlor, or 0.5% pyrethrins or allethrin in combination with synergists at the rate of 2 gallons per 1000 square feet of surface. This should be done at least three weeks before grain or cereal products are stored. DDT may be the treatment chemical for seed storage areas.

Newly harvested grain can be protected from infestation through the first season of storage by adding a commercially prepared powder (Pyrenone) composed of 0.08% pyrethrins, 1.1% piperonyl butoxide, and 98.82% inert carrier. This is distributed throughout the grain as it is put into bins at the rate of 75 pounds per 1000 bushels. A 1% premium grade malathion-wheat flour dust at the rate of 60 pounds per 1000 bushels is also approved as a grain protectant. Malathion may be sprayed on the grains by mixing 1 pint of 57% emulsifiable concentrate in 2 to 5 gallons of water and applying this to 1000 bushels.

Inert dusts of hydrated lime, magnesium oxide, silica gel, rock phosphates, or aluminum oxide protect seeds having a moisture content of 12% or less when applied at the rate of 1 ounce per bushel. Beans or other seeds so treated must be thoroughly washed before they are used as food. This control method is little practiced. Seeds for planting can be protected by mixing 1 ounce of either 3% DDT dust or 1% lindane dust per bushel. These chemicals are effective for long periods regardless of the moisture content of the seed. They are poisonous and the seed should be so labelled and never used as food for any animals.

Surface activity of Indian meal moth larvae can be prevented in stored

shelled corn if the top layer is sprayed in June and August with white mineral oil at the rate of 2 quarts per 100 square feet of surface grain.

Insect-free grains can be stored in bags impregnated with 10% DDT for almost eighteen months without insect damage. More powerful insecticides such as chlordane and lindane also are effective in resisting penetration, but none of these chemicals are practical in containers intended for packaged foods because of the danger of possible contamination. Fabric and paper bags impregnated with pyrethrins and synergists have afforded considerable protection against penetration by insects and may be of practical value.

Inspections should be made every thirty days of all grains in storage in regions 2, 3, and 4 (Fig. 519) to determine the need for control measures. The presence of adult grain insects indicates the need for immediate fumigation. These inspections can be less frequent in region 2 because lower temperatures prevail which retard development. Where grain is held over from one year to the next, it should be examined carefully and fumigated at the first sign of infestation.

Fumigate all old grain which cannot be removed from storage before new grain is binned. In grain elevators, wheat that is to be stored for over one month should be fumigated within a week after it is received. Unprotected farm-stored grains should be fumigated within six weeks after harvest.

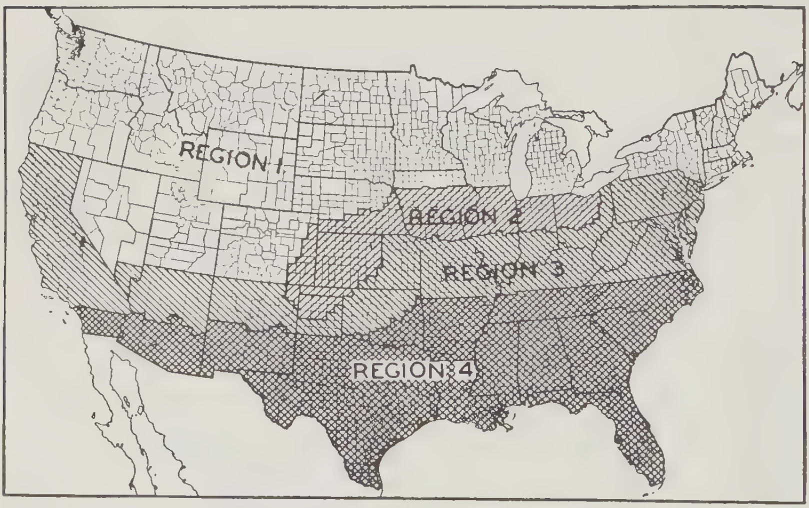


Fig. 519. Grain storage conditions in different regions: region 1, relatively safe; region 2, loss may occur in some years; region 3, hazardous every year—inspection and fumigation recommended; region 4, farm storage unsafe and not recommended. (Cotton, U.S.D.A.)

The accompanying table suggests fumigants and dosages for each. The first four materials listed can be used in any fumigation but are more often recommended for farm grain storage. They are liquids whose vapors are heavier than air and therefore should be applied at the top of the grain

	Dosage per 1000 Bushels	
Fumigant	Wooden Bins	Concrete or Metal Bins
Carbon tetrachloride, 100%	6 gal.	3 gal.
Carbon tetrachloride-carbon disulfide, 80%-20%	4 gal.	2 gal.
Ethylene dichloride-carbon tetrachloride, 75%-25%	8 gal.	4 gal.
Carbon tetrachloride-ethylene dichloride-ethylene dibromide, 60%-35%-5%	4 gal.	2 gal.
Calcium cyanide	20 lb.	10 lb.
Chloropicrin	4 lb.	2 lb.

or other materials to be treated. Chloropicrin and calcium cyanide are generally used in grain elevators and should be applied continuously to the grain stream as the bins are filled by means of especially designed applicators. Chloropicrin on grains with a moisture content of 12% or higher results in lowered germination. Methyl bromide alone, or in combination (4 to 1) with chloropicrin or ethylene dibromide, has met with success in fumigating storage warehouses and controlling surface infestations of Indian meal moths in grain elevators. These materials are generally applied at the rate of 1 to 1.5 pounds per 1000 cubic feet of empty storage space. Tablets of aluminum phosphide (Phostoxin), on exposure to air, generate phosphine gas which has proved effective in killing stored grain pests. Slight modification of some of the basic fumigant mixtures in the table are also available; some of these contain a small percentage of sulfur dioxide or other irritating chemicals as warning gases.

All fumigants are poisonous and care should be exercised in their use. For commercial products, follow the directions of the manufacturer.

Most insects are not active at temperatures below 50° F. If infested grain or other food products are cooled artificially or naturally, owing to the prevailing winter temperatures of a given region, development is retarded. Most stored-product pests are killed by an exposure of seven days to temperatures of 15° to 20° F.

Superheating is also employed as a control measure at times. An exposure of ten minutes to a temperature of 140° F. is fatal to all stored-product pests. Because of the insulating effect of these products considerable time is required to allow for heat penetration in large quantities of

grain. Special grain driers are available which force hot or warm air through layers of grain. Tests have shown that the germination of wheat, rye, oats, and buckwheat apparently is not impaired by artificial drying with heated air at 120°, 140°, and 160° F.

References: R. T. Cotton, *Insect Pests of Stored Grain and Grain Products,* Burgess Publishing Co., Minneapolis, Minn., 1963; *Nebr. Agr. Exp. Sta. Cir.* 62, 1940; *Mont. Agr. Exp. Sta. Bul.* 297, 1935; *Ill. Ext. Cir.* 512, 1941; *Minn. Agr. Exp. Sta. Bul.* 340, 1947; *Ky. Agr. Exp. Sta. Bul.* 571, 1951; *U.S.D.A. Farmers' Bul.* 1880, 1941; 1906, 1942; 1260, 1953; *Cir.* 462, 1938; 720, 1945; E-783, 1949; *Leaflet* 195, 1940; 235, 1943; 345, 1953; *Yearbook of Agriculture,* pp. 629–639, 1952; *Minn. Agr. Exp. Sta. Bul.* 425, 1954; *Can. Dept. Agr. Pub.* 1131, 1961; *Proc. Ent. Soc. Wash.* 64:43–50, 1962; *Kans. Agr. Exp. Sta. Bul.* 416, 1960.

MISCELLANEOUS PESTS OF FOODS

Cheese Skipper, *Piophila casei* (L.), is the larva of a shiny black fly, 4 to 5 mm. long. It is a pest of wide distribution in this country and in other parts of the world. The larva is a white, slender-bodied maggot, about $\frac{1}{3}$ inch in length, tapering toward the head. It attacks cheese of various kinds and cured smoked meats. The name "skipper" comes from the fact that the larva is capable of jumping or skipping short distances. Several generations may be produced during the year.

Control is accomplished by providing insect-free storage with 30-mesh screening on all doors and windows. The paraffin-coated cloth covering on cheese should be carefully applied to prevent possible places of entry. Infestations in storage can be eliminated by fumigation, raising the temperature to 125° F. or lowering the temperature to 40° F. Proper disposal of infested foods is also recommended.

Pomace or Vinegar Flies, *Drosophila melanogaster* Meigen and other species in the same genus, are often extremely numerous and annoying especially during the fruit-canning season, and particularly at processing plants. These tiny flies are attracted to well-ripened and fermenting fruit produce. The life cycle may be completed in about ten days at temperatures of 77° F., resulting in many overlapping generations.

Any practice in harvesting and marketing that prevents damage to produce and accelerates the time between picking and ultimate consumption or processing will help prevent infestation by this pest. Prompt disposal of fermenting fruits and vegetables will greatly reduce fly populations and should be practiced any place such produce exists.

Field grown tomatoes have been protected by applications of diazinon, malathion, or aldrin at four to five day intervals. To determine the need for treatment place several intentionally slit ripe tomatoes under the vines at various places in the field in late afternoon; if eggs are seen in

the slits the next morning, following examination with a magnifying glass, it is time to begin insecticide applications.

Good control is achieved without residue problems by treating harvested fruits and vegetables with a freshly mixed dust containing 1% piperonyl butoxide and 0.1% pyrethrins immediately following picking and preceding processing.

Outside walls of canning plants and inside walls, ceilings, and other areas of structures used for holding unprocessed produce may be sprayed with diazinon, naled, or ronnel. Avoid contaminating processing equipment or produce with these chemicals. Culls and refuse at processing plants may be treated with dusts or granules of diazinon, malathion, or ronnel.

Reference: *U.S.D.A. Farmers' Bul.* 2189, 1962.

Larder Beetle, *Dermestes lardarius* L., and the black larder beetle, *Dermestes ater* DeGeer, are occasional pests of cured meats, cheese, and other food products of animal origin. Primarily scavengers, these insects are often found in dried remains of dead animals, including insects. Both species are approximately $\frac{1}{4}$ inch in length, robust, and black in color; the larder beetle has a dull yellow band across the base of the elytra. The larvae are also similar, brown and hairy, like most dermestids. Ordinary sanitation prevents serious infestation. Providing insect-free storage by applying residual sprays of DDT on the walls is also suggested. Hides or furs can be protected by DDT, methoxychlor, or lindane, as recommended for clothes moths.

Red-Legged Ham Beetle, *Necrobia rufipes* (DeGeer), is fairly slender, flattened, about $\frac{1}{5}$ inch in length, and shiny green with red legs. Although widely distributed, this insect has not been a problem in this country but may occasionally be found feeding in the same situations as the larder beetles.

Flour, Grain, or Cheese Mites in the family Acaridae sometimes become abundant in stored foods, as their common names imply. Some mites are associated with flour or grains and the condition known as "baker's" or "grocer's itch" is caused by certain species. One important species in flour, grain, and cereal products is the grain mite, *Acarus siro* L. Other species are the mushroom mite, *Tyrophagus putrescentiae* (Schrank), and the cheese mite, *T. castellanii* (Hirst), which are pests of mushrooms, cheese, as well as cereals. Fumigating with 1 pound of methyl bromide per 1000 cubic feet has given good control. Direct contact sprays containing synergized pyrethrins has also given satisfactory control. Dipping waxed cheese blocks in a 4% solution of sodium o-phenylphenate mixed with

5% gelatin kills resting stages and eggs. Wiping lightly infested cheese blocks with mineral oil or cottonseed oil also helps eliminate mites.

Reference: *J. Econ. Ent.*, 46:844–849, 1953; 48:754–755, 1955; 52:237–240, 514–518, 1959.

Khapra Beetle, *Trogoderma granarium* Everts, is known to have been present in the San Joaquin valley in 1946. It has spread through southern California into Arizona, New Mexico, Texas, and Mexico. Occasionally it is found in widely scattered areas in shipments of infested products. It is native to India. Grain and cereal products are more seriously damaged, but there seems to be little in the way of dried vegetable and animal products that it will not attack. Development is more rapid in milled cereal products than in whole grains. Larvae of this dermestid are able to develop in foods with a moisture content of less than 2%. Eradication is hampered owing to its habit of crawling into spaces of infested structures, which are difficult to reach with residual sprays and toxic concentrations of fumigants. Control recommendations are the same as those for other grain insects. Infested areas are under federal quarantine and an eradication program is in effect.

References: *Proc. N.C. States Branch, Ent. Soc. Amer.*, 10:70–71, 1955; *J. Econ. Ent.*, 48:332–333, 1955; 52:312–319, 1959; 57:305–314, 1964; *U.S.D.A.* PA-436, 1961.

HOUSE ANTS

Order Hymenoptera, Family Formicidae

Several species of ants invade houses. They are important largely because of the food they contaminate and the annoyance caused by their presence. A few large species occasionally come into houses, but it is mainly the smaller ones that cause the most trouble.

Ants are social insects that live in colonies or nests, in which remain the egg-laying queens, the larvae, pupae, and many young ants. The workers, all sterile females, care for the colony and forage for food. Usually in the spring or early summer ant colonies produce winged males and females, which have the potentialities for starting new colonies; many, however, are unsuccessful. After mating the males or kings die.

More common species are the Pharaoh ant, *Monomorium pharaonis* (L.), the little black ant, *M. minimum* (Buckley), the pavement ant, *Tetramorium caespitum* (L.), the thief ant, *Solenopsis molesta* (Say), the imported fire ant, *S. saevissima richteri* Forel, the fire ant, *S. geminata* (F.), the large yellow ant, *Acanthomyops interjectus* (Mayr), the Argentine ant, *Iridomyrmex humilis* (Mayr), and the black carpenter ant, *Camponotus pennsylvanicus* DeGeer (see Figs. 520, 521, and 522).

Pharaoh ants are about 2 mm. in length and red-yellow, commonly nesting in the walls of heated buildings and feeding on a wide variety of foods. The thief ant is very similar in appearance but smaller in size;

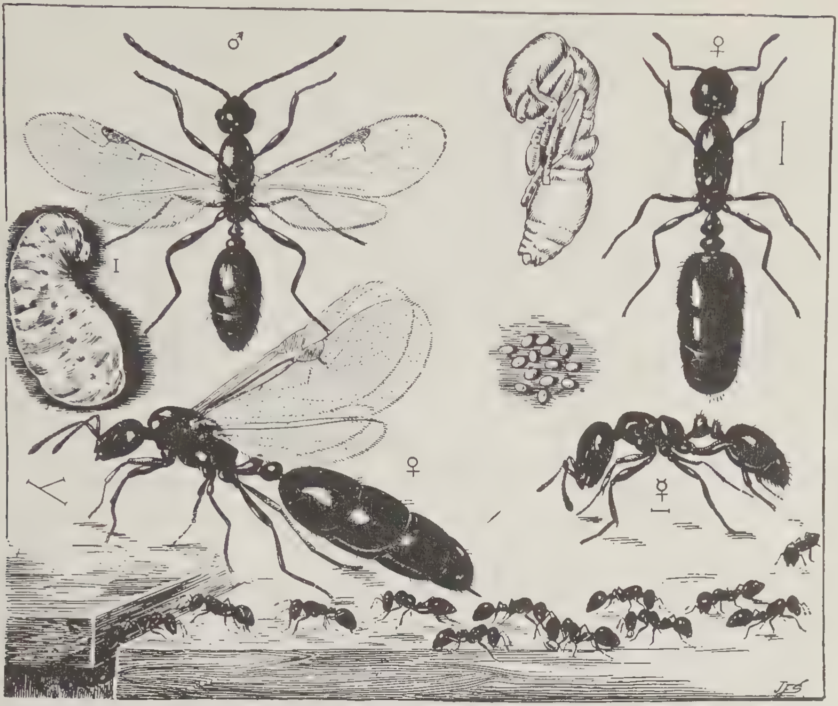


Fig. 520. The little black ant, *Monomorium minimum* (Buckley), showing several stages and activities. (U.S.D.A.)

It nests in the soil and is troublesome only during warm seasons. The little black ant is about 3 mm. long, nearly black in color, and nests both in the soil and in houses. The pavement ant is black, much larger, and nests in the soil, often under stones and other objects. Argentine ants are discussed on p. 558. In the South they are serious household pests. Carpenter ants are black and approach or exceed $\frac{1}{2}$ inch in length, commonly infesting stumps, logs, dead branches of trees, and timber in houses and other buildings. The imported fire ant builds mounds in the field and does damage to agricultural crops. In addition, it has a severe sting that makes it annoying to persons in the infested area, which is primarily southern United States.

Ants in the home can be eliminated by treating the trail of the workers to the point of entrance and then the nest itself, if it can be reached, with 2% chlordane solution or 5% chlordane dust. Do not use the solutions near an open flame because they are combustible, or on asphalt tile because they dissolve asphalt. Solutions may be applied with a small sprayer or

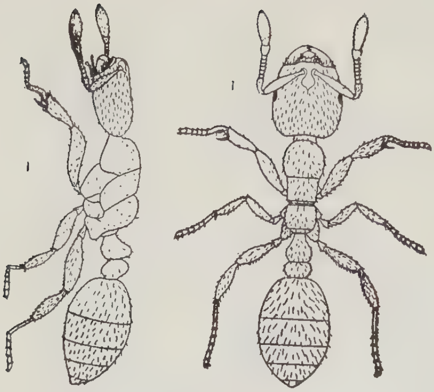


Fig. 521. Side and dorsal views of the fire ant, *Solenopsis geminata* (F.).

Fig. 522. Pharaoh ant, *Monomorium pharaonis* (L.). Top left, enlargement of mandible. (Riley.)

a paint brush, and dusts may be applied with a hand duster. Treating foundation walls and the soil around the house, particularly near the kitchen, will often eliminate the ant problem and make it unnecessary to apply insecticide inside.

Dusts, wettable powders, emulsifiable concentrates, or granular formulations may be applied outdoors around the house and in the lawn. Treat 1000 square feet of area with either 3 level tablespoonfuls of 50% chlordane wettable powder or 2.5 teaspoonfuls of 75% emulsifiable concentrate in sufficient water to give uniform coverage, or 0.5 pound of 5% dust. The water formulations can be applied with a sprayer or a sprinkling can. Carpenter ants can be eliminated by applying the insecticides to the trees or timber in which they are working.

Other insecticides equally as good as chlordane are 2% malathion, 0.5 to 1% heptachlor, aldrin, dieldrin, lindane, diazinon, or dichlorvos. Mirex is a good chemical for killing ants in fields where safety to wildlife is important.

In ant-infested places, where residual insecticides are not desirable, the following poisoned bait has given effective control of Pharaoh, as well as other ant species:

Thallium sulfate	5.5 g.
Extracted honey	3 oz.
Granulated sugar	1 lb.
Water	1 pt.
Benzoate of soda	5 g.

Mix the sugar, honey, and benzoate of soda with the water and heat to

almost boiling. Then add the thallium sulfate, stir until all is in solution, and allow to cool. This preparation should be made in a chemical hood since the vapors are *poisonous*. To be effective for longer periods, the bait must not dry out. A cardboard pillbox having one or two holes $\frac{1}{8}$ inch in diameter punched through the side of the lid, and the inside bottom part coated with melted paraffin, will serve as an inexpensive dispenser for the baits and help avoid drying. Care should be exercised to prevent children or pets from getting into poisoned baits. Store properly labeled, unused bait in a cool place.

References: *U.S.D.A. Leaflet* 147, 1937; PA-368, 1962; *Home and Garden Bul.* 96, 1964; *Tech. Bul.* 1326, 1965; *J. Econ. Ent.*, 43:565, 1950; 54:45–47, 1961; 57:331–333, 1964.

SUBTERRANEAN TERMITES

Order Isoptera, Family Rhinotermitidae

Termites, often called white ants, are neither true ants nor are they always white. True ants are constricted where the abdomen joins the thorax, whereas the termite abdomen is broad at this juncture. The majority of the individuals in a termite colony are white, but the winged swarm stages are black.

There are many kinds of termites in the world, some of which live entirely in dry or damp wood. These species are in the genus *Kalotermes* and are found principally in the southern coastal states of the United States. Subterranean termites are by far the most destructive species in North America and commonly infest wood in the soil or wood that can be reached from the soil by means of covered runways. The eastern subterranean termite, *Reticulitermes flavipes* (Kollar) is generally distributed throughout eastern United States and adjoining Canadian provinces; the western subterranean termite, *R. hesperus* Banks, occurs widely on the Pacific Coast and eastward to Nevada and Idaho; the arid land subterranean termite, *R. tibialis* Banks, is found in abundance primarily west of the Mississippi River. Other species found in the southeastern states are *R. hageni* Banks and *R. virginicus* Banks. They occur primarily in the region southward from Philadelphia, Pennsylvania, to Oklahoma.

The principal food of termites is cellulose obtained from wood and other plant tissues. Serious damage results to wooden buildings (Fig. 523), fence posts, telephone poles, paper, fiber board, and fabrics derived from cotton and other plants. Termites occasionally injure living plants, but this is of minor importance. They are able to obtain nourishment from a cellulose diet because of the presence in their digestive tracts of certain protozoa and other microorganisms, which possess enzymes capable of converting the cellulose into starches and sugars.

Termites are social insects and produce different forms or castes. These

Fig. 523. Work of the common termite. (Mich. Agr. Exp. Sta.)

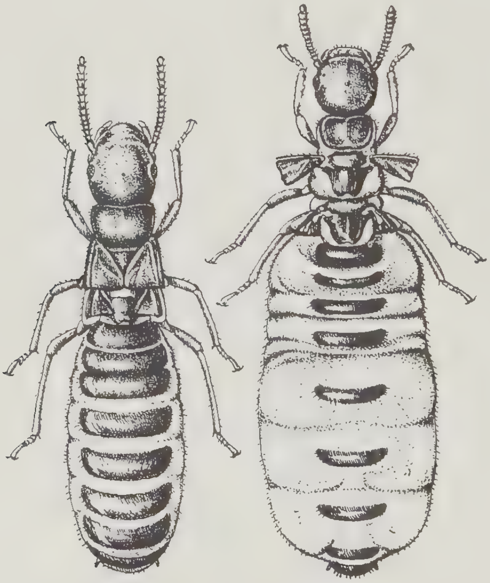


Fig. 524. The subterranean termite, *Reticulitermes flavipes* (Kollar), king on the left and queen on the right. The wing bases are still evident. (U.S.D.A.)

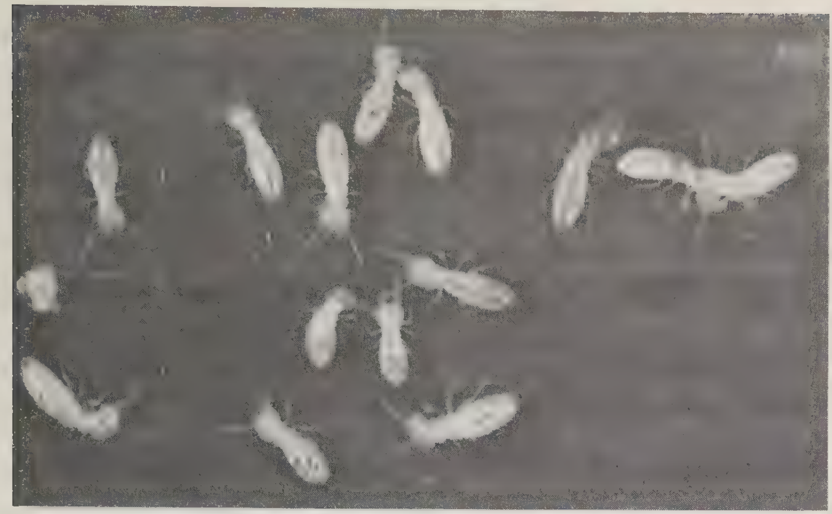


Fig. 525. Termite workers, and a soldier at top right.

include winged, dark-colored males and females which develop into kings and queens (Fig. 524), short-winged and wingless supplementary reproductives of both sexes, wingless workers of both sexes, and wingless forms with large brown heads and jaws, called soldiers. The winged forms are produced by a colony only once a year, usually in the spring, and these are capable of establishing new colonies. All wingless forms are whitish, soft-bodied, and scarcely $\frac{1}{4}$ inch in length (Fig. 525). After a colony is started the workers have the duties of feeding the queen and young, making runways, and searching for food. The soldiers guard the colony from attacks of other insects, principally ants. Should the queen be killed, the supplementary reproductives can reproduce their own kind, as well as workers and soldiers. This results in a colony that never swarms.

Subterranean termites are most numerous in moist, warm soil containing an abundance of wood or other cellulose material. They may invade buildings by constructing runways composed of soil, chewed wood, excrement, and saliva, over the surfaces of foundation walls or through cracks in the foundation or concrete floors. Damage to wood is often not evident from outward appearance because the termites leave the thin outer layer of wood intact and eat only the central portions. An infestation can often be discovered by jabbing at suspected damaged timbers with a sharp tool such as a pocket knife or screw driver. The emergence of the winged reproductive termites from a building or the soil near-by is often the first indication of the presence of a termite colony.

When planning new structures it is important to consider means of

preventing termite damage by proper design and construction. The following are suggested preventive measures: avoid leaving pieces of wood forms or scraps of lumber adjacent to the foundation or in fill material under porches, terraces, or steps; place the building on a solid, carefully built foundation; allow clearance of at least 18 inches beneath all wood substructures; provide for thorough drainage of the soil beneath the building and around the foundation; provide for ventilation under buildings without basements; avoid contact between the woodwork of the building and the soil, install wooden basement partitions, posts, and stair carriages after the concrete floor is poured; properly install metal shields of copper or zinc on top of the foundation.

Prevention of damage to railroad ties, telephone poles, fence posts, or bridge timbers is accomplished by pressure-impregnating these items with coal-tar creosote, zinc chloride, chromated zinc chloride, zinc arsenite, or pentachlorophenol. This is done by commercial firms with special equipment and trained personnel.

Chemical control in buildings is accomplished by treating the soil around the foundation or other places of possible termite entry with chlordane, heptachlor, aldrin, dieldrin, or lindane. These chemicals applied as emulsions give long-lasting protection because they possess both contact and fumigant action, do not have objectionable odors, and are not phytotoxic at the required concentrations. An accepted procedure is to prepare a 1% chlordane emulsion and apply this to the soil at the rate of 2 gallons per lineal 5 feet for the first foot at ground level and 1 gallon per lineal 5 feet from grade level to footing. In some situations it will be necessary to trench along the entire perimeter of the building and gradually add the chemical as the trench is filled. For homes with basements the dosage is 4 gallons per lineal 5 feet. Considerable saving of time results if a soil auger can be used to make holes near the foundation about 18 inches apart, in which the emulsion is poured to saturate the soil and form a chemical barrier to termite entry. Slab floors and porches should be drilled and treated at the rate of 1 gallon per 10 square feet of area. Treating the foundation area of new homes and other buildings at the time of construction is good insurance against termite attacks. If aldrin, dieldrin, heptachlor, or lindane are used in place of chlordane, prepare emulsions at concentrations of 0.5%. Emulsifiable formulations are preferred but wettable powders can be used.

DDT, TDE, toxaphene, methoxychlor, pentachlorophenol, and sodium pentachlorophenate are inferior to the recommended chemicals, although they will provide protection against termite attacks. Dry wood termites are controlled by fumigation with HCN or methyl bromide.

If the termite problem is especially difficult, consult your extension entomologist or a reliable pest-control operator.

References: *U.S.D.A. Home & Garden Bul.* 64, 1963; *Farmers' Bul.* 2018, 1958; *J. Econ. Ent.*, 45:235–237, 1952; 46:527–528, 1953; *Fla. Ent. Bul.* 157, 1954; *Conn. Agr. Exp. Sta. Cir.* 218, 1961.

POWDER POST BEETLES

Order Coleoptera

These destroyers of seasoned wood rate next to the termites in the amount of damage they do. Most of this damage is caused by the larvae eating and tunnelling through timber in lumberyards, homes, other buildings, and manufactured wood products, such as furniture and handles of tools. The interior portion of the wood is reduced to a fine powder, and

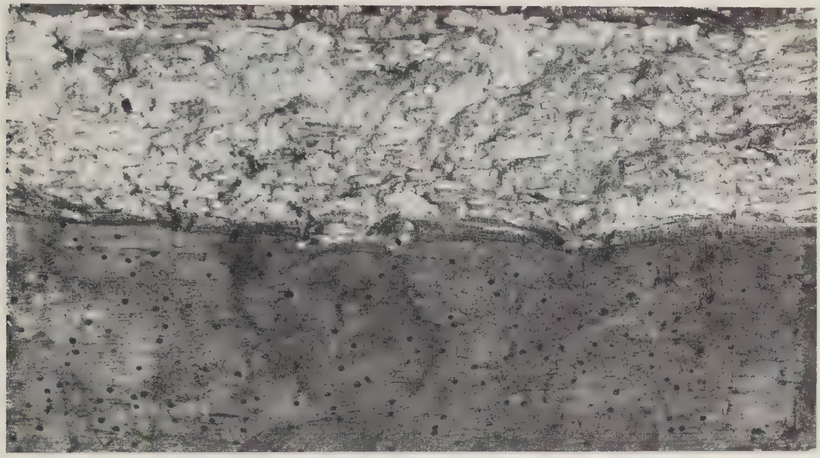


Fig. 526. Damage to wood by powder post beetles. Note adult emergence holes.

the surface becomes perforated with small holes (Fig. 526). Several species in each of the following families are usually the most destructive: Anobiidae, Lyctidae, and Bostrichidae. Where feasible, sanitation measures are of value in controlling these pests. Furniture and other wood products can be fumigated, methyl bromide and HCN being the common fumigants. Where facilities are available, heat treatment at 125° F. or higher will kill all stages if this temperature is maintained for an hour or more throughout the infested materials. More permanent protection is provided by treating wood with oil base solutions containing either 5% DDT, 2% chlordane, 1% lindane, 0.5% dieldrin, or 5% pentachlorophenol.

References: *U.S.D.A. Leaflet* 358, 1959; 501, 1961; *Farmers' Bul.* 2104, 1956; *Tech. Bul. 1157, 1957.*

COCKROACHES

Order Orthoptera, Family Blattidae

Many species of cockroaches occur throughout the world, some of which infest the household and are frequently found in restaurants, hotels, hospitals, grocery stores, slaughterhouses, offices, and libraries. The damage they do may be relatively slight, but their presence is so objectionable that they are considered among the worst of domestic pests.

Some of the more common species are the American cockroach, *Periplaneta americana* (L.) (Fig. 527), the German cockroach, *Blattella germanica* (L.), the oriental cockroach, *Blatta orientalis* L. (Fig. 528), the

Fig. 527. The American cockroach, *Periplaneta americana* (L.): *a*, view from above; *b*, from beneath. (U.S.D.A.)

Fig. 528. The German cockroach, *Blattella germanica* (L.); the oriental cockroach, *Blatta orientalis* L., female and male; and the American cockroach, *Periplaneta americana* (L.), from left to right. (Conn. Agr. Exp. Sta.)

Australian cockroach, *Periplaneta australasiae* (F.), and the brown-banded cockroach, *Supella supellectilium* (Serv.).

Eggs of roaches are produced in capsules or öothecae, which may be carried for several days by the female, protuding from the tip of her abdomen. Some species drop the capsules in places that they frequent; others, like the German roach, carry them until hatching takes place. Hatching of the egg capsules that are dropped may take place in two or more weeks. An egg capsule of the German roach contains twenty-five to thirty eggs, those of the American and oriental twelve to thirteen, and that of the brown-banded about eighteen. The young nymphs develop rather slowly and are found in the same places as the adults. The German roach has two or three generations per year, whereas the larger species require about a year or more to mature.

Adults of the German and brown-banded roaches are about $\frac{1}{2}$ inch long and light brown in color, the German having two dark stripes on the pronotum and the brown-banded having two light yellow cross-bands on the wings. The female brown-banded has darker brown wings with the same markings. These two species are common in dwellings and restaurants. Adults of the American roach are red-brown and 2 inches long; they frequent slaughterhouses, hotels, and bakeries. Oriental roach adults are almost black and about $1\frac{1}{2}$ inches long. The females are practically wingless, and the males have wings which do not reach the tip of the abdomen. Roaches of this species thrive best in damp places and are sometimes called "waterbugs." The Australian roach resembles the American species but is slightly smaller and has a bright yellow stripe on the outer edge of the basal half of the fore wings. It may be found in houses but is more common in greenhouses.

All roaches live concealed during the day, and scurry about and feed at night. They are omnivorous and foods of all kinds may be contaminated with their excretions and offensive odor. Because of their flattened bodies they can hide in crevices behind baseboards, kitchen cupboards, under sinks and drainboards, cracks in the plaster, or any darkened area.

Control may be accomplished by treating the areas where they hide during the day or the surfaces on which they are apt to crawl at night with 2% chlordane, malathion, or ronnel, 1% Dipterex, or dicapthon, 0.5% diazinon, dieldrin, DDVP, or lindane. Where German cockroaches have become resistant to the chlorinated hydrocarbons treat with diazinon, malathion, Baygon, or ronnel. These chemicals may be applied with a small hand sprayer or paint brush. Dust formulations are also effective but the concentration of the chemical is usually double that given for spraying. Silica aerogels alone or in combination with the various insecticides mentioned have proved satisfactory in some situations. Phosphorus

baits have been useful in controlling American cockroaches. Pyrethrum powder with synergists is often combined with sodium fluoride or other dry formulations to act as a knockdown agent. Solutions of pyrethrins in combination with previously recommended chemicals are applied with atomizers or thermal fog machines for cockroach control in stores and warehouses. Eliminating feeding and breeding areas should not be overlooked in the control program.

References: *U.S.D.A. Leaflet* 430, 1962; *Yearbook of Agriculture*, p. 472, 1952; *Can. Dept. Agr. Pub.* 109, 1953; *J. Econ. Ent.*, 57:327–328, 1964.

SILVERFISH AND THE FIREBRAT

Order Thysanura, Family Lepismatidae

Both these insects are known as silverfish. They are similar in that both are slender, wingless, scale-covered insects, measuring slightly more than $\frac{3}{8}$ inch in length, with three long, slender tail-like appendages at the tip of the abdomen and two long, slender antennae on the head. They differ in size and coloration, the silverfish, *Lepisma saccharina* L., being smaller and uniform silver, or pearl gray; the firebrat, *Thermobia domestica* (Packard), is larger with dusky markings on the body (Fig. 529).

Silverfish thrive best in damp, warm basements but may cause damage in any part of a house or public building. The firebrat is more likely to be found in very warm places. Old-fashioned bake ovens often became infested, and this gave rise to the name "firebrat." With their chewing mouthparts both insects eat the sizing on paper, bookbindings, wallpaper,

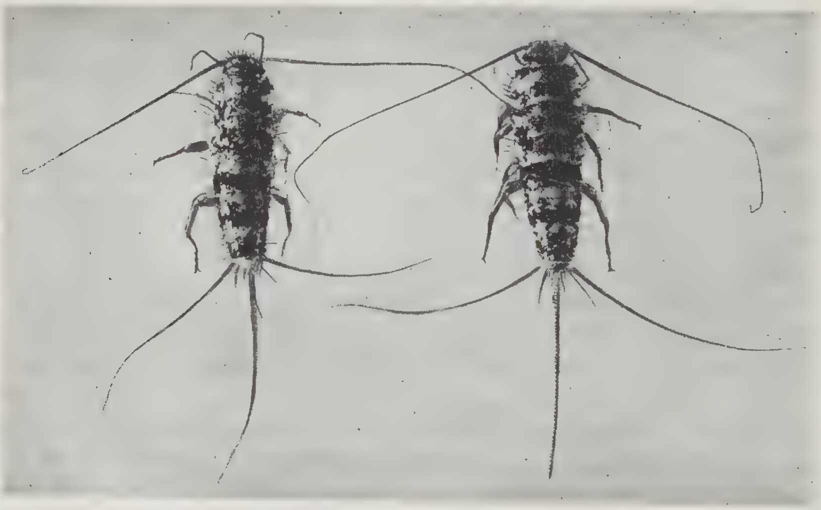


Fig. 529. The firebrat, *Thermobia domestica* (Packard).

or insulation materials. Starched clothing and curtains, or rayon, may be seriously damaged, and foods contaminated.

All life stages may be found throughout the year. The number of generations produced varies with prevailing temperature and humidity. Silverfish are said to mature in seven to twenty-four months, and firebrats in three to twenty-four months.

Control of these insects is accomplished by spraying the places they frequent with 5% DDT, 2% chlordane or malathion, 1% lindane, 0.5% diazinon or dieldrin. Dusts of these chemicals are also effective and can be used with safety in places where spray solutions are prohibitive, because the latter will dissolve asphalt tile and are combustible.

References: *U.S.D.A. Leaflet* 412, 1966; *Yearbook of Agriculture,* p. 472, 1952.

CLOTHES MOTHS

Order Lepidoptera, Family Tineidae

Quite small in size, clothes moths cause damage by the larvae feeding on articles containing wool, mohair, feathers, fur, hair, casein, fish meal, or other products of animal origin. They are world-wide in distribution.

The most common species, the webbing clothes moth, *Tineola bisselliella* (Hummel), is straw-colored without markings on the wings, and a trifle smaller than the other species. The tiny white larvae with brown heads make webs or tubes on the surface, where they feed somewhat concealed (Fig. 530). The casemaking clothes moth, *Tinea pellionella* (L.), has gray-yellow wings with faint dark markings. Its larvae form cases of silk and chewed fibers, which are carried about wherever they crawl and in which pupation later takes place. The carpet moth, *Trichophaga tapetzella* (L.), is larger than either of the other species and has wings very dark at the base with light tips (Fig. 531). This insect is smaller than the Indian meal moths, which often occur in houses and are mistaken for clothes moths. Larvae of carpet moths feed on coarse fabrics, making webs and constructing rather prominent cocoons in which they pupate.

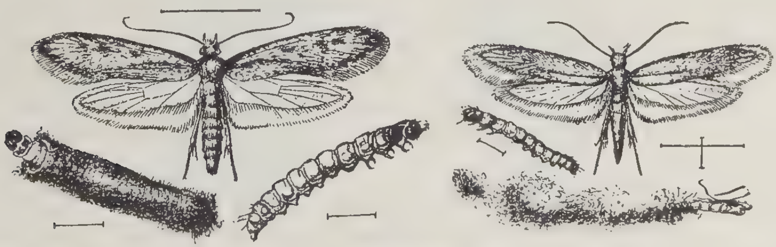


Fig. 530. The casemaking clothes moth, *Tinea pellionella* (L.), and the webbing clothes moth, *Tineola bisselliella* (Hummel). (Riley.)

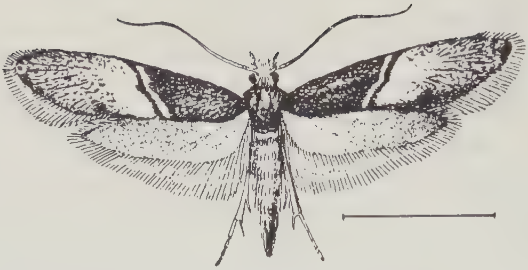


Fig. 531. The carpet moth, *Trichophaga tapetzella* (L.). (Back, U.S.D.A.)

Female moths lay 100 to 300 white eggs, which hatch normally in five or more days. Larval development requires about six weeks, and the pupal period approximately a week. The length of the life cycle is quite variable because of uneven temperatures encountered, but at 80° F. the period from egg to adult requires about fifty days. At lower temperatures this period is greatly extended.

Careful sanitation, washing, dry cleaning, vacuum cleaning, brushing of articles subject to attack, and their storage in mothproof containers often prevent damage. Winter clothing from the dry cleaners can be protected during the summer months when moths are most active by placing a small amount of paradichlorobenzene crystals in the storage container or closet. Clothing not moth-free should be placed in a closet set aside for storage and fumigated with 1 pound of PDB crystals to each 100 cubic feet of space, sealing the door with masking tape.

Heavily infested homes can be freed of clothes moths by fumigating the entire building with hydrogen cyanide, or fumigating clothes closets with a 3-to-1 mixture of ethylene dichloride and carbon tetrachloride. The more modern and efficient method is the repeated use of DDT aerosols in clothes closets, or treating infested articles or storage-closet walls and baseboards with residual sprays or dusts of 5% DDT, 5% methoxychlor, 2% chlordane, or 1% lindane, or 0.5% dieldrin. Spraying until the surface is moist is sufficient. Sodium fluosilicate solutions also give good protection only when applied directly to woolen articles. These solutions can be purchased in stores under various trade names. Whatever treatment is used, it is important to include all articles that may become infested.

Cedar-lined closets or chests high in cedar-oil content protect garments if free of all life stages of the insects when placed in such storage. Placing furs or woolen clothing in cold storage at temperatures of 42° F. or lower will kill clothes moths. Temperatures of 110° F. or higher likewise will destroy these insects.

References: *Cornell Univ. Memoir* 262, 1944; *U.S.D.A. Farmers' Bul.* 1655, 1931; *Leaflet* 145, 1938; E–858, 1953; *Home and Garden Bul.* 24, 1961; 96, 1964.

CARPET BEETLES

Order Coleoptera, Family Dermestidae

Carpet beetles can cause great damage to home furnishings and clothing containing wool, hair, fur, feathers, and other animal substances. They can also subsist on dead insects and food products such as cereals. Four species commonly found in dwellings are the black carpet beetle, *Attagenus piceus* (Olivier), the common carpet beetle, *Anthrenus scrophulariae* (L.), the varied carpet beetle, *A. verbasci* (L.), and the furniture carpet beetle, *A. flavipes* LeConte. All species are widely distributed in the world.

None of these insects in any stage of growth has a body length greater than $\frac{1}{4}$ inch, except very large specimens of black carpet beetle larvae, which may be almost $\frac{1}{2}$ inch long. The adults are beetles which are broad or elongate oval. They feign death when disturbed.

The adult black carpet beetle (Fig. 532) is uniformly black with brown legs. The other species have a black-to-brown body color, which is concealed by a dense covering of small scales that form patterns helpful in differentiating the species. Adults of the carpet beetle (Fig. 532) have a dull red band extending down the center of the back. The adults of the furniture carpet beetle are mottled with patches of white, yellow, and black, and are light underneath. The varied carpet beetle adults are the smallest species and resemble furniture carpet beetles but have scales of less brilliancy.

Larvae of all species, except the black carpet beetle, are more or less oval in shape, the bodies covered with black, brown, or tawny hairs and

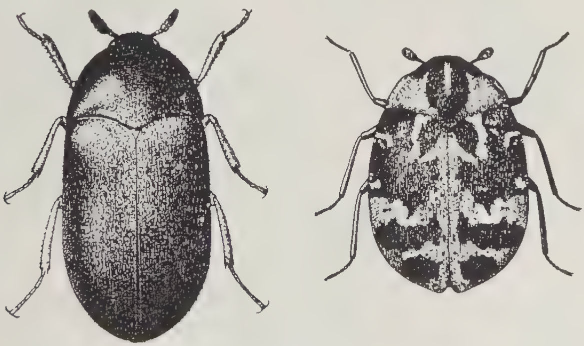


Fig. 532. The black carpet beetle, *Attagenus piceus* (Olivier), and the carpet beetle, *Anthrenus scrophulariae* (L.). (Conn. Agr. Exp. Sta.)

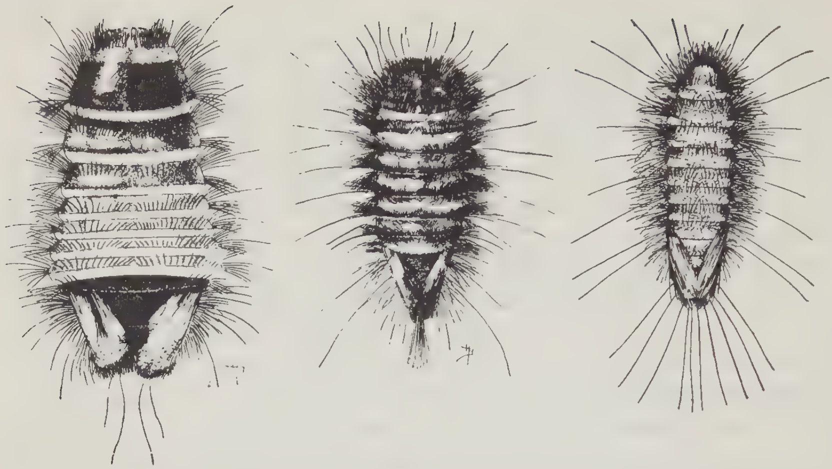


Fig. 533. Larvae: of the varied carpet beetle (left), the furniture carpet beetle (center), and the carpet beetle (right). (Back, U.S.D.A., and Turner and Walden, Conn. Agr. Exp. Sta.)

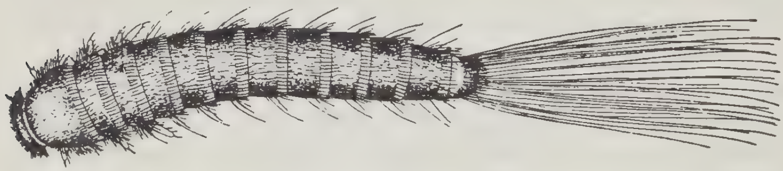


Fig. 534. Larva of the black carpet beetle. (Turner and Walden, Conn. Agr. Exp. Sta.)

three tufts of bristles on each side of the posterior end (Fig. 533). The larvae of the black carpet beetles are elongated, golden to chocolate brown, with a tuft of long hairs at the end of the body (Fig. 534).

Adult beetles fly readily, are attracted to light, and are often found crawling on curtains and windows. They react favorably to sunlight, are readily seen out-of-doors late in the spring feeding on pollen of flowers, and in city areas undoubtedly fly from house to house on warm days. Each female beetle deposits approximately 100 white eggs which hatch normally in eight to fifteen days. Larval growth requires the most time and varies considerably with the temperature and food supply. They molt six to ten or more times, and the old exoskeletons are often seen about infested articles. The pupal stage may last almost two weeks. The period from egg to adult is quite varied for each species, requiring 274 to 600 days for the black carpet beetle, 251 to 657 days for the varied carpet beetles, 126 to

422 days for the furniture carpet beetle, and 78 to 439 days for the common carpet beetle. Usually only one or two generations occur each year.

Methods of control suggested for clothes moths are generally effective against carpet beetles. However, carpet beetles are more difficult to kill and the residual sprays of DDT, chlordane, dieldrin, or lindane are strongly recommended, especially for use on and under the edges of rugs, under and on top of rug pads, around baseboards and floor moldings. Tank-type vacuum cleaners are also suggested, for reaching the covers and crevices around floors, baseboards, and moldings to eliminate sources of food and developing life stages. Reasonably permanent mothproofing requires application during manufacture of materials, such as Mitin FF and Eulans, which are combined with the fibers.

References: *U.S.D.A. Leaflet* 150, 1938; *Yearbook of Agriculture*, p. 474, 1952; *Home and Garden Bul.* 24, 1961; *Cornell Univ. Memoir* 240, 1941.

HOUSE CRICKET

Acheta domesticus (L.), Family Gryllidae

Sometimes house crickets enter dwellings, and are annoying because of their presence and frequent habit of eating holes in clothing and furnishings. This species (Fig. 535) is amber or light brown in color and active chiefly at night. The overwintering eggs hatch in late spring and adults appear

Fig. 535. House crickets, *Acheta domesticus* (L.), male (left), and female (right). Occasional minor household pests in some localities. (Britton, Conn. Agr. Exp. Sta.)

in late summer, with only 1 generation occurring per year. House crickets can be eliminated with 2% chlordane sprays or 5% chlordane dusts. One per cent lindane sprays or dusts may also be used. Treating window screens, basement window frames, and places around the foundation wall will kill the crickets before they gain entrance.

23

Insects Injurious to Man and Domestic Animals

It is estimated that in the United States livestock pests alone cause annual losses amounting to 850 million dollars. Wasted food, damaged hides, and lowered production of milk, meat, eggs, and wool comprise these losses. All animals lose energy and weight fighting off attacks of blood-sucking arthropods. In addition, some species cause great annoyance simply by egg-laying. Others carry and transmit organisms causing disease, some of which are fatal; others result in reduced performance of the animal.

It is difficult to make an accurate estimate of the monetary loss suffered from insects directly detrimental to man, but time lost from work, loss in business at resort and vacation areas, cost of screening homes and buildings, lowered efficiency, medical expense, and similar items would amount to a considerable sum.

With the proper use of many of the more recently developed insecticides it is now possible to greatly reduce these losses. Although much still remains to be learned, progress in combatting this group of pests has been rapid in recent years.

LICE ON LIVESTOCK

Lice on domesticated animals are world-wide in distribution. They are of two types, the biting or chewing lice and the sucking lice; on livestock there may be several species of each. Both are wingless, quite small in size, usually 2 to 4 mm. in length, with well-developed claws on their legs. Biting lice (order Mallophaga) generally have broader heads, and their mandibles are used in feeding on hair, scales of skin, and the blood which oozes after the skin has been gnawed. Scabs which form where the skin is broken either by the mouthparts or claws may also be eaten. Sucking lice (order Anoplura) have narrow heads, puncture the skin, and suck up the blood directly in the liquid state. The irritation from these parasites causes the animals to rub and scratch, resulting in partly denuded areas of

skin, lowered vitality, and loss in production of meat or milk. Some species of lice are also involved in the transmission of organisms causing disease.

Lice in both groups pass their entire life cycle on the host animals. The eggs are usually attached to hair or feathers, and the young resemble the adults except for their smaller size. Development from egg to adult varies from two to four weeks depending on the species. Repeat generations occur throughout the year. Spread from one animal to another is through contact. Horses, cattle, sheep, and goats are attacked by both kinds of lice. Only sucking lice attack hogs and man, and only biting lice infest birds, including poultry.

The biting lice on livestock are placed in the family Trichodectidae and the sucking lice in the family Haematopinidae.

The horse biting louse, *Bovicola equi* (L.) (Fig. 536), is 2 mm. in length, reddish yellow with faint darker bands. They may become numerous on neglected animals but are rare on horses that receive proper care. A less common species is *Trichodectes pilosus* Giebel.

The horse sucking louse, *Haematopinus asini* (L.) (Fig. 537), is considerably larger than the biting species and is grayish brown to almost lead color. It is more likely to infest poorly kept horses on the range than those used regularly, and tends to become more numerous and to injure the animals more than do other species.

The cattle biting louse, *Bovicola bovis* (L.), is probably the most common species attacking cattle, although not so injurious as some of the

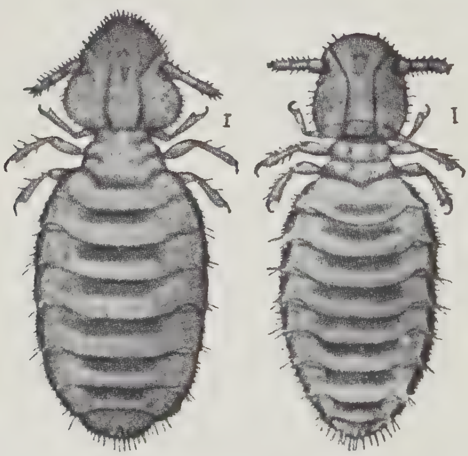


Fig. 536. The cattle biting louse, *Bovicola bovis* (L.) (left), and the horse biting louse, *Bovicola equi* (L.) (right). (Osborn, U.S.D.A.)

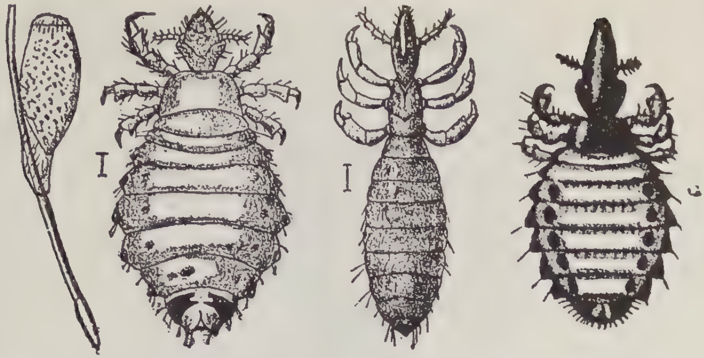


Fig. 537. The short-nosed cattle louse, *Haematopinus eurysternus* (Nitzsch), and its egg; the long-nosed cattle louse, *Linognathus vituli* (L.); and the horse sucking louse, *Haematopinus asini* (L.), named from left to right. (Osborn.)

others. It is distinguished by its reddish brown color, which is the basis for the other common name, "little red cattle louse." A small species, 2 mm. maximum length, it is considerably flattened with darker pigmented areas on the dorsal side of the abdomen (Fig. 536).

The short-nosed cattle louse, *Haematopinus eurysternus* (Nitzsch) (Fig. 537), is slate gray, larger than the biting louse, with a short, narrow, more pointed head. It is more commonly found on mature animals and is generally more resistant to the usual control measures.

The long-nosed cattle louse, *Linognathus vituli* (L.) (Fig. 537), is blue-black, smaller than the other cattle sucking louse, and much more slender with a longer, narrower head. It is generally more abundant on young stock and dairy cattle. Another sucking louse, *Solenoptes capillatus* Enderlein, is about half as large as the short-nosed species and is quite blue in color, suggesting the common name "little blue cattle louse." The cattle tail louse, *Haematopinus quadripertusus* Fahrenholz, is a sucking louse sometimes found on cattle in the South.

The hog louse, *Haematopinus suis* (L.) (Fig. 538), is the largest of the sucking lice; it is 3 to 4 mm. in length, with a rather broad body and prominent head and proboscis. It is the only louse found on hogs and often becomes very abundant.

The sheep biting louse, *Bovicola ovis* (L.), is the smallest and the most important species attacking sheep. Other species of lesser importance are the sucking foot louse, *Linognathus pedalis* (Osborn), and the sucking body louse, *Haematopinus ovillus* (Neuman) (Fig. 539).

The angora goat biting louse, *Bovicola limbata* (Gerv.), the goat biting

Fig. 538. The hog louse, *Haematopinus suis* (L.). (U.S.D.A.)

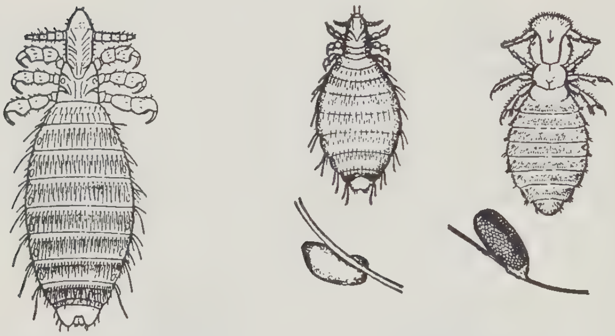


Fig. 539. The sucking body louse of sheep, *Haematopinus ovillus* (Neuman); the sheep sucking foot louse, *Linognathus pedalis* (Osborn); and the sheep biting louse, *Bovicola ovis* (L.); named from left to right. Eggs of the last two species are illustrated. (Mote.)

louse, *B. caprae* (Gurlt), the goat sucking lice, *Linognathus stenopsis* (Burm.), and *L. africanus* Kellogg and Paine, are common species found attacking goats.

If all livestock were treated two or three times at two-week intervals, lice could be eradicated. Materials recommended as powders or sprays on dairy cattle in production or beef animals about to be slaughtered are rotenone, syngerized pyrethrins, or Ciodrin. Other cattle, horses, hogs, sheep, and goats can be rid of lice by the above named materials and also by powders, sprays, or dips of methoxychlor, malathion, ronnel, lindane, toxaphene, Ruelene (pour-on treatment), coumaphos, dioxathion, chlor-

dane, diazinon (sheep only), or DDT. Lindane and DDT are recommended for treating only sheep and hogs and only one application should be made. Granules of 5% ronnel applied at the rate of $\frac{1}{2}$ pound per 100 square feet of bedding area have proved effective in hog louse control. The ease with which this treatment is made makes it popular. The cattle tail louse and the sucking foot louse of sheep are more difficult to eradicate. Properly operated back-rubbers set up in beef cattle feed lot areas will reduce louse populations. Commercial or homemade devices that enable hogs to oil themselves by rubbing contribute to the control of hog lice.

References: *Cornell Bul.* 832, 1946; *U.S.D.A. Bur. Ent. Cir.* E-762, 1951; *Yearbook of Agriculture,* pp. 662–666, 1952; *Farmers' Bul.* 909, 1953; *Leaflet* 456, 1960; *J. Econ. Ent.,* 52:980–981, 1959; 54:821, 1961; 57:42–44, 1964; *Can. Dept. Agr. Pub.* 1006, 1957.

HORSE AND DEER FLIES

Order Diptera, Family Tabanidae

The familiar blood-sucking flies of this family constitute one of the major problems of the livestock industry in this country, as well as in other parts of the world. Horse and deer flies feed on many warm-blooded animals but cause the greatest annoyance and injury to cattle and horses. They frequently attack man along summer beaches. Besides the lowering of vitality from loss of blood and pain from their bites, these flies are capable of carrying and transmitting the organisms causing such diseases as anthrax, surra, and tularemia. Many species have been described, and the dominant forms in one region may not be important in other areas. Some common destructive species are the black horse fly, *Tabanus atratus* Fabricius, the striped horse fly, *T. lineola* Fabricius, *T. sulcifrons* Macquart, *T. quinquevittatus* Wiedemann, and the deer flies, *Chrysops parvulus* Daecke, and *C. niger* Macquart.

Horse flies are considerably larger than deer flies; they are heavybodied and from $\frac{3}{4}$ of an inch to over an inch in length (Fig. 540). The smaller species are black, brown, or gray and often have brilliant green eyes, sometimes crossed by reddish golden bands which disappear when the fly is dead. The largest species are brown to black in color and often slightly striped. Horse flies may be present from June to the middle of September.

Deer flies are slightly larger than house flies, mostly yellow or black in color with darker stripes on the abdomen and dark markings on the wings. The season for these flies is short, usually three or four weeks in June or July.

Both horse and deer flies breed in water or in wet soil. Dark-colored

Fig. 540. Adult and larva of the black horse fly, *Tabanus atratus* Fabricius. (Ky. Agr. Exp. Sta.)

masses of eggs are deposited on low-growing plants or other objects near the edge of ponds, lakes, or streams. Hatching occurs in a week or more, and the larvae burrow in the mud, feeding on other insects, tiny crustacea, and aquatic or semiaquatic organisms. The fully grown, gray larvae of the larger species may reach a length of almost 2 inches, and have darker-colored bands (Fig. 540). Development from egg to adult may require only a few months, or one to two years, depending on the species.

No satisfactory methods have been developed for control of horse flies and deer flies. It is impractical in most regions to eliminate the breeding places. Destruction of oviposition sites gives some promise as a control measure. Prevention of attack by providing daytime shelters for animals and allowing them to pasture at night is of value since the flies do not bite at night. Sprays containing 0.1% pyrethrins and 1.0% piperonyl butoxide give repellency protection of one to three days. Chemicals applied for controlling other species of flies attacking livestock offer some relief from horse and deer fly annoyance.

References: *Ark. Bul.* 332, 1936; *U.S.D.A. Misc. Pub.* 305, 1938; *Yearbook of Agriculture*, pp. 659–660, 1952; *Agr. Handbook* 290, 1965; *Tech. Bul.* 1295, 1964.

STABLE FLY

Stomoxys calcitrans (L.), Family Muscidae

Found throughout the United States and most of the world, stable flies commonly attack mules, horses, cattle, hogs, dogs, cats, sheep, goats, and man. In some parts of the country, stable flies are known as dog flies because they often attack dogs viciously, especially around the ears. The adults feed only on blood, and the irritation from their puncturing of the skin along with loss of blood results in nervous animals. Constantly fighting the flies is also fatiguing. During severe outbreaks beef animals make very little weight gains, and milk production of dairy cows may be reduced 10 to 50%.

The adult is almost identical to the house fly, but it can be readily distinguished from the latter by the piercing-sucking beak which projects forward (Fig. 541). The house fly mouthparts are sucking or sponging and project downward from the head.

Breeding takes place in wet straw, manure, vegetable and fruit refuse, peanut litter, and marine grass windrows along the coast. The tiny, cream white eggs are laid in these moist habitats; hatching occurs in two to three days. The larval period lasts twelve to thirty days or longer, depending on the prevailing weather. Development from egg to adult requires from three to six weeks or more. In northern climates the overwintering stage is larvae or pupae; in southern areas breeding is continuous.

Control may be accomplished through one, or a combination, of the following methods: destruction of breeding places; application of residual insecticides to buildings, sheds, corrals, and other places where the flies rest; and application of insecticides to the animals or breeding areas.

Where manure or other breeding material cannot be spread often on the fields, treating with emulsions of diazinon, DDVP, dimethoate, ronnel, or malathion will kill the larvae and prevent reproduction until the chemicals are dissipated. Do not use diazinon in poultry houses.

Fig. 541. The stable fly, *Stomoxys calcitrans* (L.), adult female. (U.S.D.A.)

Residual wall sprays containing dimethoate, ronnel, malathion, diazinon, naled, DDVP, or methoxychlor may be applied inside dairy barns, but only ronnel, malathion, diazinon, and DDVP are approved for use inside milk processing rooms. Baytex or fenthion is another effective chemical but recommended only for beef and hog barns. Remove animals before spraying and avoid contamination of feed troughs, water fountains, and milking equipment. Spray until the surfaces are wet to the point of run-off.

Space sprays, aerosols, or barn-fogging devices containing organic thiocyanates, synergized pyrethrins or allethrin are useful in temporarily reducing fly populations in dairy barns.

Stable flies stay on animals only long enough to get a blood meal; therefore spraying the animals is less effective than spraying the premises. It is, however, a desirable additional control measure during severe outbreaks. Dairy cows are the animals most often treated but beef cattle, horses, and mules should not be neglected if high populations of flies prevail. Oil-base mist-type sprays containing Ciodrin, organic thiocyanates, synergized pyrethrins or allethrin and/or repellents are recommended. Treat only the outer hair coat of the animal. Treadle sprayers are useful for such treatments.

To prevent stable flies from annoying people, use indalone repellent on the clothing and exposed parts of the body. Spraying vegetation in the vicinity of outdoor gatherings with DDT, methoxychlor, or chlordane at 1% concentration will afford some relief.

References: *U.S.D.A. Leaflet* 338, 1953; *Agr. Handbook* 290, 1965; *Conn. Agr. Exp. Sta. Bul.* 650, 1962.

The false stable fly, *Muscina stabulans* (Fallen), is often mistaken for the stable fly. It resembles both the stable fly and the house fly but lacks the piercing-sucking mouthparts of the stable fly and is a trifle larger than the house fly. Its abdominal region is gray rather than yellow. At times this insect makes up a high percentage of the fly population in a given area, but it is usually less important than either of the species it so closely resembles. The false stable fly is also similar to the stable fly in breeding habits and is controlled in the same way.

HORN FLY

Haematobia irritans (L.), Family Muscidae

Introduced into North America from Europe about 1890, horn flies have since spread over the entire country. The blood-sucking adults feed chiefly on cattle but may attack sheep, goats, horses, hogs, and other animals. Most of their adult life is spent on the animals, and their bites cause extreme annoyance, resulting in 10 to 20% reduction of milk pro-

Fig. 542. Egg, larva, puparium, and adult of the horn fly. (U.S.D.A.)

duction in dairy cows and reduction of weight gains of beef cattle by as much as one-half pound per day. On cattle, they have the habit of congregating about the ears, the base of the horns, on the flanks, withers, back, and belly. Higher populations occur on black cattle.

The horn fly resembles the house fly; it is slightly slenderer and only about half as large (Fig. 542). Its proboscis or beak is similar to that of the stable fly. The eggs, laid only on fresh animal feces, hatch in a few days, and the larvae feed and develop, changing to puparia in the soil or feces, with adults emerging soon afterwards. About two weeks are required for development from egg to adult.

The most effective way to rid animals of horn flies is to apply an insecticide. Approved chemicals for dairy cows in production are Ciodrin, DDVP, organic thiocyanates, and synergized pyrethrins. Daily applications are necessary for all materials except Ciodrin which should be applied weekly.

Good control has resulted by applying powders of methoxychlor or malathion to dairy or beef animals every two or three weeks. The recommended dosage is one heaping tablespoonful (10 grams) of 50% methoxychlor WP or three tablespoonfuls ($1\frac{1}{2}$ oz.) of 5% malathion powder, applied to the back of each animal and rubbed into the hair.

Approved chemicals for animals other than dairy cows in production are Ciodrin, coumaphos, dioxathion, malathion, methoxychlor, ronnel, Ruelene, and toxaphene. Commercially prepared products are available containing the proper concentrations of these chemicals for treating livestock. Treadle sprayers are useful in the application of these insecticides.

Excellent control has resulted from commercial or homemade backrubbers. A homemade device consists of a cable (chain, wire rope, or several strands of heavy wire), suspended from two 4-foot fence posts

set 16 feet apart, so as to sag 18 inches from the ground. Or the cable may be fastened to the top of a 4-foot post and anchored at ground level 15 to 20 feet away. The cable is carefully wrapped with burlap bags which overlap one another and are tied securely with twine. The burlap is soaked with 1 gallon of the appropriate chemical and this is replenished at one- to two-week intervals. For dairy cows, treat the sacks with an oil solution of 1% Ciodrin. For other cattle, the sacks may be treated with 5% DDT, methoxychlor, or toxaphene, 1% ronnel, or 1.5% dioxathion.

References: *U.S.D.A. Leaflet* 291, 1950; 388, 1963; *J. Econ. Ent.*, 45:121–122; 329–334, 1952; 57:371–372, 1964.

FACE FLY

Musca autumnalis **DeGeer, Family Muscidae**

This native European insect was first found in North America at Middleton, Nova Scotia, Canada, in 1952 and has since spread throughout most of eastern and central United States. The fly habitually clusters around the eyes, nostrils, and mouths of cattle, sucking up the secretions in those areas as well as salivary deposits left on other parts of the body caused by animals licking themselves or others. During epidemic outbreaks over 100 flies have been observed on each animal. This constant annoyance is reflected in lowered production of milk and additional time necessary to finish beef animals for slaughter. These flies may also be carriers of pink eye and eye worms. Occasionally other domestic animals in the vicinity may be disturbed by face flies.

The insects pass the winter in buildings as adults. They resemble house flies, but they are slightly larger and darker. Warm spring temperatures activate those that survive the winter, and they seek fresh cattle dung where feeding and oviposition occur. The tiny pale yellow eggs which have a gray-black stalk projecting at one end are laid in groups of five to eight. Hatching occurs in one day. The white maggots feed in the dung and pass through three instars before changing to white puparia in the soil. In another ten days new adults begin to emerge, starting the cycle anew. This is continued with repeated generations throughout the summer. Although flies overwinter in buildings they avoid entering them in the summer months.

Fly sprays and backrubbers as outlined for controlling stable and horn flies give some relief from face fly attacks. Sirup baits containing 0.5% dichlorvos or naled applied daily to the forehead of each animal and sprays of Ciodrin and synergized pyrethrins afford additional relief from this pest.

References: *Can. Entom.* 85:422–423, 1953; 92:360–365, 1960; *J. Econ. Ent.*, 53:450–451,

1960; 54:1147–1151, 1961; 57:631–636, 1964; *Proc. N.C. Branch Ent. Soc. Amer.* 17:135–136, 1962; *Ann. Ent. Soc. Amer.* 57:563–569, 1964.

HORSE BOT FLIES

Order Diptera, Family Gasterophilidae

Three species of bot flies universally attack horses, mules, and donkeys. They are the common horse bot fly, *Gasterophilus intestinalis* (DeGeer), the nose bot fly, *G. haemorrhoidalis* (L.), and the throat bot fly, *G. nasalis* (L.). The nose bot fly is spreading gradually but is prevalent primarily in Illinois, Kansas, Nebraska, Iowa, Minnesota, North and South Dakota, Colorado, Wyoming, Montana, Idaho, and in adjacent areas of southern Canada. Common and throat bot flies are found in almost all states.

Horses become nervous and excited during the period of adult flight and egg-laying, and seem to instinctively fear them. Adult flies are present when the animals jerk their heads, stamp their feet, stand in pastures with their throats over each other's backs, rub their noses and lips on objects, or run as if being chased. The larvae or bots infest the alimentary tract causing digestive disturbance, irritation to the lining, and obstruction of the normal passage of food materials.

The adult flies of all three species are much alike in appearance and resemble honey bees in size and coloration, but have only one pair of wings and a curved-under abdomen (Fig. 543). In the northern states they appear early in June and are present until the first killing frost in the fall. However, each individual may live a period of only a few days to possibly as long as three weeks. Egg-laying starts soon after the adults emerge and continues throughout the summer, some eggs remaining viable for almost three months. Larvae (Figs. 544 and 545) occur in the stomach throughout the year but are most abundant during late fall and winter. Only one generation develops each year.

Eggs of the common bot fly (Fig. 546) are deposited principally on the

Fig. 543. The horse bot fly. (Froggatt.)

Fig. 544. Larvae of bot flies attached to the wall of the stomach of a horse. (Osborn, U.S.D.A.)

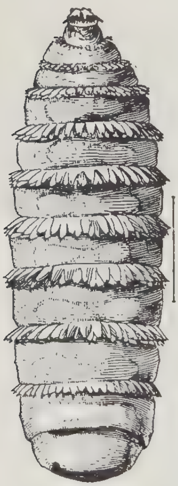


Fig. 545. Larva of the horse bot fly. (Froggatt.)

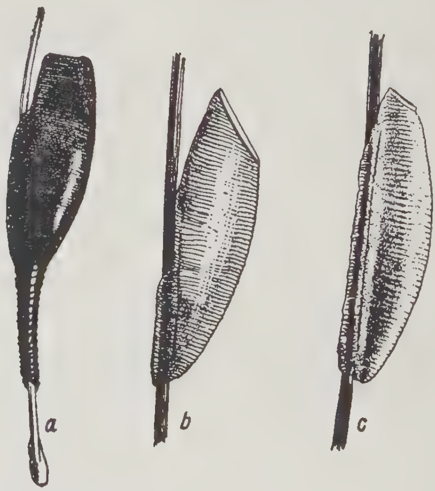


Fig. 546. Eggs of the three species of bot flies attacking horses: *a, G. haemorrhoidalis* (L.); *b, G. intestinalis* DeGeer; *c, G. nasalis* (L.). (Dove, U.S.D.A.)

fore legs but are also found on the mane, belly, and hind legs. After an incubation period of approximately a week or more they hatch immediately upon exposure to the warmth and moisture of the horse's lips in nibbling or scratching the legs. In this way the larvae get into the mouth where they burrow into and along the upper surface of the tongue.

After three or four weeks they leave the tongue and pass into the stomach, where they complete their growth in nine or ten months while attached to the lining (Fig. 544), then move out of the body with the feces. Pupation takes place in the soil; the period lasts about a month or more.

The throat bot fly eggs are laid on the hairs of the chin, jaws, and throat. These hatch in some five days, and the tiny larvae crawl to the mouth where they are found principally around the gums of the molar teeth. After three or four weeks they pass through the stomach into the duodenum where they remain attached until the following spring, then move out of the body with the feces, and pupate in the soil. The pupal period lasts about forty-four days.

Eggs of the nose bot fly are laid on the short hairs along the edges of the lips; hatching takes place in about three days. The tiny larvae burrow into the lining of the lips and mouth for a few weeks causing great irritation, then move to the stomach where they remain attached until spring. This species has the habit of attaching itself to the walls of the rectum and anus before leaving the body with the feces. Pupation occurs in the soil, and the period varies from twenty-one to sixty-eight days.

Horses may suffer from bot infestation during all periods of the year, because many of the grown larvae do not pass from the intestinal tract before the new ones begin to appear.

Heavy frosts in the autumn kill the adults; after a period of three or four weeks, the young throat and nose bots leave the tissues of the mouth, and no unhatched eggs of these species remain. However, many eggs of the common bot fly remain unhatched but viable. The simplest method for eliminating these eggs is to vigorously apply warm water (115°–120° F.) with a rag or sponge. Hatching takes place instantly, and the tiny larvae die from exposure. Research indicates that it is not necessary to add 2% phenol or coal-tar creosote to the water, as was done formerly. Warming the eggs with water should be done two weeks after frost has killed all adults. Four weeks later, or about December, in the northern states, there should be community-wide internal treatment of all animals with carbon disulfide. Farther south bot fly activity is extended, and the most practical procedure is to treat in September and again in January.

To be most effective all food and water should be withheld from the animal for a period of eighteen hours before the treatment. Carbon disulfide is administered by a veterinarian with a capsule or stomach tube. The dosage is 6 fluid drams for each 1000 pounds' body weight. Feeding and watering the animal may take place three hours after treatment. Usually in six hours or more, dead bot larvae begin passing out with the feces. This treatment is also highly effective in removing the large intestinal roundworm.

A more recent accepted treatment is to give trichlorfon as a single dose orally in feed, as a capsule, or as a drench. Using 99% technical grade trichlorfon, the dosage is 1.8 grams/100 pounds body weight. Do not treat more often than once every thirty days, and do not treat horses to be used for food.

Keeping animals in the stable during the day and pasturing them at night will avoid infestation. Mechanical protectors offer some relief from nose bot fly annoyance. Sponging the nose and throat area or spraying with repellent-type fly sprays containing pyrethrins and piperonyl butoxide should be of some value in control.

References: *U.S.D.A. Leaflet* 450, 1959; *Can. Dept. Agr. Pub.* 604, 1938.

CATTLE GRUBS OR OX WARBLES

Order Diptera, Family Oestridae

One of the most important insect problems with which the owner of cattle has to deal is the control of cattle grubs or heel flies. The losses to the livestock industry have been estimated at $160 million annually. These losses occur in several ways. Cattle instinctively fear the adult flies during egg-laying. They run wildly, sometimes injuring themselves in attempting to get away. The result is lower milk flow, poor weight gains, or even loss in body weight. Skin penetration causes irritation to the animal and damage to the flesh, which must be trimmed out in slaughtered animals. Perforation of the skin on the back means a reduction in the value of the hides as leather.

Two species are important, the common cattle grub, *Hypoderma line-*

Fig. 547. The northern cattle grub, *Hypoderma bovis* (L.), and the common cattle grub, *H. lineatum* (de Villers). (Mote, Ohio Agr. Exp. Sta.)

atum (de Villers), which is found throughout the United States, in Canada and Mexico, and the northern cattle grub, *H. bovis* (L.), which is found in southern Canada and the northern three-fourths of the United States. The northern cattle grub is a trifle larger in the adult stage and differs in some details of habits and developmental history, but both species are essentially the same in the damage they do.

Adults of the grubs are hairy, yellow and black flies about the size of the honey bee (Fig. 547). The more common species fastens its yellowish white eggs to the hairs of the legs, usually on the heels, arranged in rows of several on a hair. The northern species attaches only one egg to a hair. These eggs are not often seen because they are attached close to the skin and sometimes covered by adjacent hairs. Egg-laying ordinarily takes place only on sunny days; each female is capable of depositing about 500 eggs during a life span of a week or more.

Hatching occurs in a few days, and the spiny larvae (Fig. 548) bore through the skin and migrate upward between the muscles to the abdominal and chest cavities. During the next six to eight months they burrow about over the surface of the paunch, intestines, spleen, and other organs. Larvae of the common species are especially numerous between the muscular and mucous layers of the gullet. In these situations the

Fig. 548. Larvae of the cattle grub or ox warble. (Bishopp et al., U.S.D.A.)

Fig. 549. A cattle grub larva in position under the skin of the animal. (U.S.D.A.)

larvae are slender and range in length from $\frac{1}{10}$ to $\frac{2}{3}$ of an inch. In the fall, winter, and spring they migrate through the muscle tissues of the back, sometimes in the spinal canal (northern species), eventually reaching the permanent locations under the skin on the back of the animal (Fig. 549). Here the larva cuts a small hole in the skin, which it enlarges as growth proceeds until finally, after a period of thirty-five to ninety days, full development is reached; it squeezes through the opening, falls to the ground, burrows in, and pupates. The northern cattle grub develops in the same way but requires a period of fifty to one hundred days to complete its growth and consequently appears later as lumps under the skin. The pupal period lasts eighteen to seventy-seven days for the common species and fifteen to twenty-five days for the northern species. Adults are usually present from May to July and begin to lay eggs about an hour after emerging from the pupae. There is only one generation per year for both species (Fig. 550).

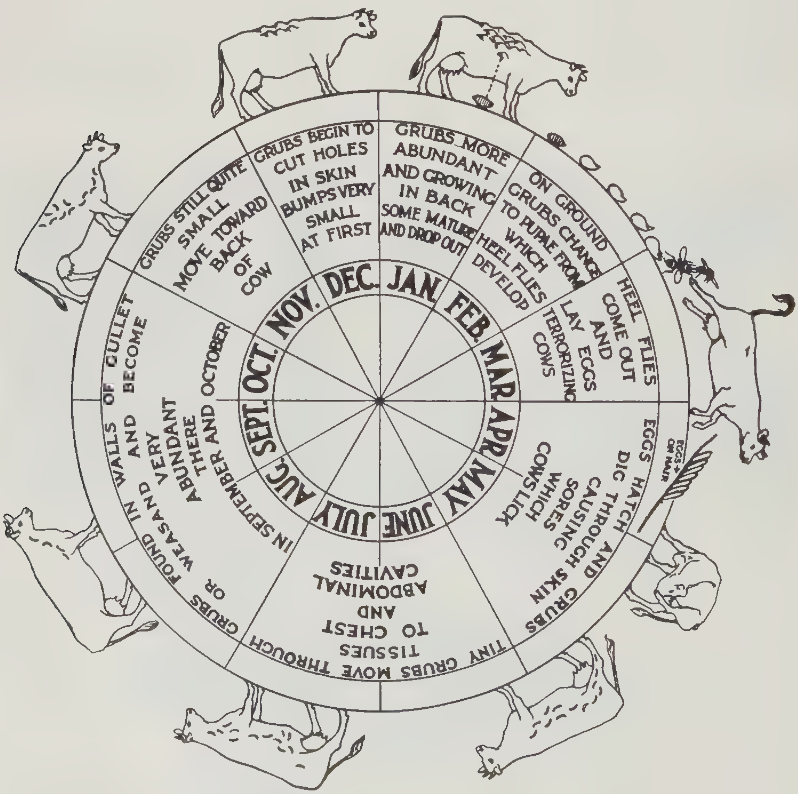


Fig. 550. Diagram of the life cycle of the common cattle grub in southern United States. (U.S.D.A.)

Control of grubs consists of treating the backs of all infested animals on a community-wide basis during the period the grubs are in that region (and before they emerge) with derris or cubé powder as a dust, wash, spray, or ointment. Three or four treatments are recommended at intervals of three or four weeks, starting around three weeks after the first holes are detected on the back. For dusting the proportion should be one part (by weight) of the derris or cubé powder (containing 5% rotenone) to two parts of talc, pyrophyllite, or a similar diluent. Apply the dust from a can with a perforated top, and rub it in thoroughly. A wash consisting of 12 ounces of derris or cubé powder mixed in a gallon of water containing 2 ounces of neutral soap powder, can be applied from a quart jar with a perforated lid and worked into the grub holes with a stiff bristled brush. An ointment consisting of one part of derris or cubé powder and ten parts of petrolatum has given excellent results if applied directly in each grub hole. High-pressure sprays applied directly to the backs of the animals is a more rapid method of treating large numbers. Add 8 pounds of derris or cubé powder (containing 5% rotenone) to each 100 gallons of water. With the sprayer adjusted to deliver 5 gallons per minute, one person can treat the back of an animal every ten seconds.

Rotenone is the only insecticide recommended for grub control in lactating dairy cows. However, beef and nonlactating animals can also be treated with the new systemic insecticides, coumaphos, ronnel, and Ruelene. Follow carefully the directions of the manufacturer of these products.

Infestation may be avoided by keeping cattle in the stable during the day. Hand extraction with forceps or squeezing has proved effective, especially for animals with elastic skin such as the Jerseys and Guernseys. Holsteins have thick, tough hides, and it is difficult to remove the grubs by squeezing. Care must be exercised to avoid crushing the grubs within the skin because their body contents may cause anaphylactic shock. Some cattlemen claim that they have lighter infestations when all cattle are sprayed with residual-type fly sprays, especially on the legs and body, during the period that adults are present and eggs are hatching.

References: *J. Econ. Ent.*, 41:783–787, 1948; *U.S.D.A. Leaflet* 527, 1965; *Ann. Rep. Ent. Soc. Ont.*, 76–80, 1950; *Ohio Ext. Bul.* 473, 1966.

SCREW-WORM

Cochliomyia hominivorax (Coq.), Family Calliphoridae

Screw-worms have been known in Texas since about 1842 and are still found in that state, in New Mexico, Arizona, Central and South America. All other infestations in the United States have been eradicated by releasing laboratory reared sterile male flies in those areas. In past years, during the summer, this pest has been found as far north as South Dakota, Kentucky, Virginia, and New Jersey. This is due primarily to shipments of

Fig. 551. The screw-worm fly, *Cochliomyia hominivorax* (Coq.). (U.S.D.A.)

infested animals into these areas. Such infestations are eliminated with the coming of cold winter weather.

Any warm-blooded animal is subject to screw-worm attack. Infestations have been found on all kinds of wild and domestic animals, as well as on man. Before an animal can become infested a break must occur in its body surface. Any cut or scratch, dehorning or castration operation, fly or tick bites, the navel opening of new-born animals, or a diseased condition of the skin may attract the adult flies. They are blue-green with three dark stripes on the thorax (Fig. 551) and, in size, are almost identical to the common blow flies.

Each female can lay 3000 eggs during her life span, depositing them in masses of 200 to 400 at four-day intervals. They are securely cemented together and placed along the edges of the wounds. Hatching occurs within twelve hours; the white, tapered maggots feed only on living flesh within the wound, becoming fully grown in five days (Fig. 552). They crowd together with their heads pointed inward. Infested wounds develop a bloody discharge and a disagreeable odor which attract more egg-laying females; the maggot population increases rapidly, and the animal dies if nothing is done to check them.

Mature maggots leave the wound, fall to the ground, enter the soil, and change to puparia. Adult flies normally begin emerging in one or two weeks, but this may be prolonged to almost two months by cool

Fig. 552. The screw-worm. (U.S.D.A.)

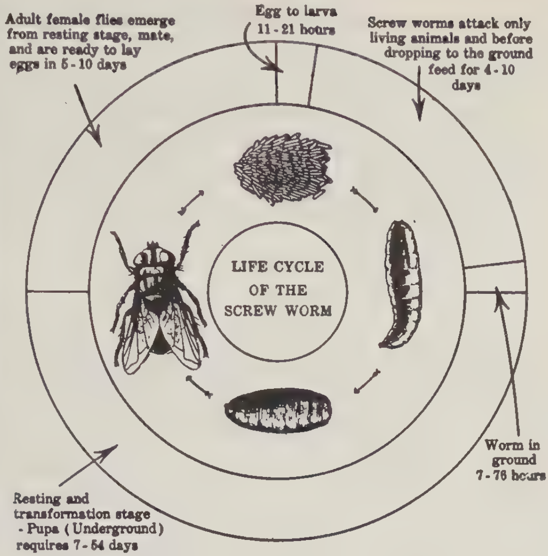


Fig. 553. Life cycle of the screw-worm fly. (U.S.D.A.)

weather. A few days after emerging the flies mate once and the females begin laying eggs on wounded animals. There may be six to ten generations per year depending on the latitude (Fig. 553). If average daily temperatures lower than 54° F. prevail for two months or more, the pupae die in the soil.

Injury from this insect may be lessened by measures which help to prevent the wounds through which entrance is gained. For example, there should be careful livestock handling, proper management so that the young are born out of fly season, rounding off sharp horns of animals, controlling ticks and flies, prompt treatment of the dam and the navel of new-born animals, limiting branding, castration, lamb docking, and dehorning to the winter period. During the fly season all livestock in a community should be examined carefully twice each week. Any wound found, whether infested or not, must be promptly treated with a good screw-worm remedy. Those recommended are EQ 335 or smears 62 and 82, preference being in the order named. EQ 335 contains (in percentages by weight) lindane, 3; pine oil, 35; mineral oil, 40 to 44; emulsifier, 8 to 12; silica aerogel, 8 to 12. This mixture does not stain and is not highly volatile. It is best applied to the entire wound area, both inside and out, with a 1-inch paint brush. Treatments should be made at seven-day intervals until the wound is healed.

Smears 62 and 82 are recommended if EQ 335 is not available. They contain the following ingredients in per cent by weight:

	Smear 62	Smear 82
Diphenylamine	35	35
Benzol	35	32
Turkey red oil	10	—
Triton X-300	—	2
n-Butyl alcohol	—	10
Lamp black	20	21

Additional remedies for screw-worm infestations in animals are the application of 5% dusts of ronnel or coumaphos once or twice a week until the wound is healed. These remedies must not be applied to lactating dairy cows.

The eradication program is being continued by the federal government, and if it is done extensively enough with Central and South American countries cooperating, eventually the screw-worm might be eliminated from the earth. In addition to releasing large numbers of sterile flies obtained from gamma radiated puparia reared in the laboratory, the great success of the program in release areas was because female flies mate only once. Released sterile females laid only infertile eggs and normal females in the area mating with sterile males likewise resulted in eggs that were infertile. This is the classic example of insect control without applying chemicals.

References: *Fla. Bul.* 86, 1936; U.S.D.A. E–813, 1951; *Agr. Handbook* 290, 1965; *Yearbook of Agriculture*, pp. 666–672, 1952; *J. Econ. Ent.*, 46:648–656, 1953; 53:1110–1116, 1960; 55:826–827, 1962; 57:324–325, 1964.

BLOW FLIES

Order Diptera, Family Calliphoridae

Some blow fly species may infest cattle, sheep, dogs, and other animals. Larvae of such flies are very similar to the screw-worm larvae except that they feed on dead as well as living animals. Common species are the black blow fly, *Phormia regina* (Meigen), the secondary screw-worm, *Cochliomyia macellaria* (F.), and the greenbottle fly, *Phaenicia sericata* (Meigen).

Sheep are most often attacked; the insects are then called fleece worms or wool maggots. The flies lay eggs in the wool, soiled by urine, feces, or warm spring rains, or combinations of these, and the maggots feed in these regions, frequently invading healthy tissues, which become in-

flamed and often infected with other organisms that result in blood poisoning and death.

Practices designed to prevent attacks of blow flies are essentially the same as those employed in screw-worm control. EQ 335 is recommended for infested animals when diluted one part with nine parts of water. Saturate the affected area thoroughly with the emulsion. Dioxathion is recommended for fleeceworm control in addition to the other remedies given under screw-worms.

SHEEP BOT FLY

Oestrus ovis L., Family Oestridae

In the larval stage this insect is also called the sheep grub or head maggot. The adult is a yellow, hairy, bee-like fly (Fig. 554), nearly $\frac{1}{2}$ inch in length. It is active most of the year in southern latitudes but only for three or four months in its northern range. During this period the eggs hatch within the body of the female, and she in turn deposits the larvae in the nostrils of sheep and goats. The maggots make their way through the nasal passages and invade the frontal sinuses, where the pressure produced as they increase in size may affect the semicircular canals, thus causing staggers or gid. It is said that they may penetrate the thin septa and reach the brain; death of the animal then results. Full-grown maggots often exceed an inch in length and are heavy-bodied. Larval development may take from four to ten months (Fig. 555), after which the larvae leave the host and change to puparia in the soil, with adult emergence four to six weeks later.

Fig. 554. Adult female of the sheep grub, *Oestrus ovis* L. (U.S.D.A.)

Fig. 555. Larvae of the sheep grub, *Oestrus ovis* L. (Courtesy of F. R. Koutz.)

The flies are active only in the daytime. Their presence can be detected by the sheep crowding together with their heads held low; this is accompanied by stamping of the feet and shaking of the head. Maggot-infested sheep often sneeze and have a mucous discharge from the nostrils.

Darkened shelters for the sheep during the months when the flies are active will afford protection from infestation. Treating the nostrils of the sheep with pine tar is of questionable value in deterring the flies from larvipositing. Once the grubs have become established in the animal, the injection of 2 fluid ounces of 3% saponified cresol into each nostril has given good control. It is suggested that this treatment be made in late autumn by a veterinarian.

Experiments with coumaphos, dimethoate, ronnel, Ruelene, Narlene, and DDVP have shown promise for controlling this pest more efficiently.

References: *J. Am. Vet. Med. Assoc.* 97:565–570, 1940; *Vet. Med.* 54:377–383, 1959; *64th Proc. U.S. Livestock Sanitary Assoc.* 178–186, 1960; *J. Econ. Ent.*, 56:530–531, 1963.

SHEEP KED

Melophagus ovinus (L.), Family Hippoboscidae

The sheep ked, also called sheep "tick," is not a true tick but a wingless, red-brown fly (Fig. 556). It is found throughout the year in the adult stage, feeding on the blood of sheep and goats with its piercing-sucking mouthparts. The larval stages develop within the body of the adult females until fully grown; they are then deposited on the wool of the sheep and in a few hours transform to puparia, which are light in color at first but change to dark brown in several hours. These remain glued to the wool, and after a period of some three weeks during summer weather

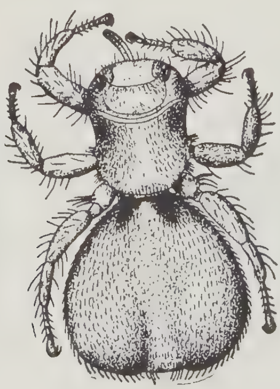


Fig. 556. The sheep ked *Melophagus ovinus* (L.). (Ky. Agr. Exp. Sta.)

and a longer period in cold weather the adults emerge, mate, and begin the cycle anew. There are several generations per year.

These insects are often more numerous on lambs and it is important that ewes be freed of them before lambing time. Control is accomplished by dipping, spraying, or dusting. Excellent control has resulted from one treatment in a dip, consisting of 8 ounces of derris or cubé powder (containing 5% rotenone) in 100 gallons of water, to which has been added two tablespoonfuls of household detergent. This formula can be sprayed with equally good results. A dust containing 1% rotenone will also control keds. Other approved control chemicals are DDT, dioxathion, coumaphos, lindane, malathion, ronnel, synergized pyrethrins, toxaphene, diazinon, and dieldrin. The last two chemicals must not be used on goats. Sheep should be dipped as soon as the shearing cuts have had an opportunity to heal. If keds are discovered too late in the season for dipping or spraying, the small flock owner will find it profitable to give individual dust treatments.

References: *Cornell Univ. Bul.* 844, 1948; *U.S.D.A. Farmers' Bul.* 2057, 1953; *Agr. Handbook* 290, 1965.

SCAB AND MANGE MITES

Order Acarina

Scab and mange of domestic animals are caused by various parasitic mites. Different varieties of the scab mite, *Psoroptes equi* Gervais, and *P. ovis* (Hering), affect cattle, sheep, goats, horses, and rabbits (Figs. 557

Fig. 557. The sheep scab mite, *Psoroptes ovis* (Hering); female (left), male (right). (Ky. Agr. Exp. Sta.)

Fig. 558. Sheep affected by scab mites. (Courtesy of F. R. Koutz.)

and 558). The mites live on the surface of the skin on any part of the body thickly covered with hair, feeding upon serum and lymph, and migrating to the periphery of the lesions formed as these become larger and encrusted with scabs. This form of mange itches severely and causes animals to scratch and rub against objects until the hair or wool comes out. The skin becomes thickened, wrinkled, and is frequently stained with blood. Transmission is usually by direct contact with infested animals or with objects against which they have rubbed.

Various species of *Chorioptes* scab mites attack the same hosts, have similar habits, and produce lesions very much like those described for *Psoroptes,* but the infestations are more localized, rarely involving the entire body of the host. For example, *C. bovis* (Gerlach) is commonly known as tail mange of cattle.

Mange mites, *Sarcoptes scabiei* (DeGeer), are also known as itch mites (Fig. 559). Several varieties attack cattle, horses, hogs, sheep, goats, dogs, rabbits, and man. The mites burrow into the tender skin areas of the host where the hair is sparse and often continue to spread until large portions of the body are affected. Nodules usually appear over and around the burrows; these burst and ooze serum, which hardens to form scabs. Intense itching causes the animals to rub and scratch, leaving open sores which frequently are invaded by bacteria. The skin becomes wrinkled and thickened as the infestation spreads. Transmission is usually by direct contact with mangy animals or with objects against which affected hosts have rubbed. Repeat overlapping generations occur throughout the year at intervals of two or three weeks.

Follicle mites of the genus *Demodex* attack domestic animals and man, causing manifestations of disease similar to those already described, by burrowing into hair follicles and oil glands. The nodules formed vary in

Fig. 559. Sarcoptic mange or itch mite. (Imes, U.S.D.A.)

size from a pinhead to as large as a marble and are filled with thick pus resulting from secondary bacterial infection. Demodectic mange is of minor importance in cattle, sheep, goats, and swine in the United States; it is, however, a serious pest of dogs, causing what is known as red mange. This mange is transmitted by direct contact; it does not itch severely, frequently not at all. Common species are the cattle follicle mite, *Demodex bovis* Stiles; the dog follicle mite, *D. canis* Leydig; the sheep follicle mite, *D. ovis* Railliet; the goat follicle mite, *D. caprae* Railliet; the hog follicle mite, *D. phylloides* Csokor; the horse follicle mite, *D. equi* Railliet; and the cat follicle mite, *D. cati* Mégnin.

Isolation of infested animals and treatment by spraying or dipping is a recommended procedure. Sheep scab mite is being rapidly eradicated in the United States by supervised state-wide dipping of all infested sheep in a 0.5% concentration of a special livestock formulation of toxaphene. In addition to toxaphene, infested animals may also be treated with 0.06% lindane and proprietary nicotine or lime-sulfur dips. Commercial lime-sulfur diluted 1 to 15 with water has been used successfully as a dip to control mange mites. Dipping livestock is sometimes done on a community-wide basis and supervised by the county agent, extension entomologist, or state veterinarian. Control of demodectic mange on small animals has been successful using a 20% benzyl benzoate ointment or a 1% rotenone solution in oil. With these materials repeat applications to the affected areas are necessary.

For controlling the itch mite on man the following formula is suggested in parts by weight: benzyl benzoate, 68; DDT, 6; benzocaine, 12; and Tween, 80, 14. This material is diluted one part with five parts of water, applied to the entire body with a sponge or cloth, and allowed to remain for twenty-four hours or longer. A second application may be necessary when the infestation is severe. All clothing, bedding, and towels of the person must be sterilized by heat.

References: *U.S.D.A. Misc. Pub.* 606, 1946; *Leaflet* 438, 1958; *S.D. Agr. Exp. Sta. Tech. Bul.* 10, 1952.

TICKS

Order Acarina, Family Ixodidae

Several species of hard-backed ticks attack both wild and domesticated animals, and occasionally man. All are ectoparasites that attach themselves to the host and suck blood, causing irritation, annoyance, and loss in vigor. This results in lower production of milk, meat, leather, and fiber. In addition to the painful wounds, the paralyzing effect from the bites, known as tick paralysis, is often more serious. Some ticks are also vectors of organisms causing dreaded diseases.

Cattle Tick, *Boöphilus annulatus* (Say), considered to be the worst of the ticks that affect livestock, has been eliminated from the United States, except possibly in the extreme southern tip of Texas. It is responsible for spreading the protozoan, *Babesia bigemina,* from affected to healthy cattle which produces the disease known as Texas fever. Both the cattle tick and the disease still exist in South and Central America and in other parts of the tropics.

When the fertilized adult female tick becomes engorged with blood she drops to the ground and produces a large mass of brown eggs, as many as 3000 or more (Fig. 560), from which hatch the six-legged seed ticks. These crawl up on vegetation, cling to any passing animals which rub against them, insert their piercing-sucking mouthparts and begin

Fig. 560. The cattle tick, *Boöphilus annulatus* (Say); adult female with egg mass.

feeding. In a week or more they molt to the eight-legged nymph, continue feeding, and in seven or more days transform to adults. These, after engorging, drop to the ground, the females laying their eggs. There may be three or more generations per year. If the seed ticks fail to attach to an animal within three to eight months, they die. If the female which has produced the eggs was from a diseased animal, the young ticks will also carry the organisms causing the disease. Although cattle reared in infested areas develop immunity to the disease, those from outside such regions are fatally affected.

American Dog Tick, *Dermacentor variabilis* (Say), is common in the eastern half of the United States; it is especially numerous in areas covered with grass or underbrush and it also occurs in the Pacific Coast states. A common pest of dogs and other wild or domesticated animals, it is also known to attack man. Aside from the annoyance and irritation from their blood-sucking habits, these ticks transmit the rickettsial organisms causing Rocky Mountain spotted fever in man and rodents. They are also capable of transmitting the organisms of tularemia and possibly relapsing fever.

In northern latitudes this tick overwinters in all stages except the egg, and unengorged adults (Fig. 561) live more than three years under favorable conditions of moderate temperature and considerable moisture. Since these ideal conditions do not always prevail many ticks live only a few weeks to three or four months. Adults are more prevalent in the spring, and after engorgement and mating the females deposit their brown eggs in large masses on the ground over a period of two to four weeks. During

Fig. 561. An unengorged female American dog tick, *Dermacentor variabilis* (Say). (U.S.D.A.)

this time, as many as 6000 eggs have been recorded from a single female. Hatching occurs in thirty or more days, and the six-legged stage crawls up on surrounding vegetation and clings to any passing animals which rub against them. The mouthparts are inserted, and blood is sucked until they are fully engorged. This requires from three to twelve days, after which the ticks drop off and molt to the eight-legged nymph. After feeding on another host they again drop off and molt into the adult stage. The cycle may be completed during a period of a few weeks to several months or a year or more.

Brown Dog Tick, *Rhipicephalus sanguineus* (Latr.), is a cosmopolitan species and a vector of the organism causing canine piroplasmosis. It also has been shown to be a vector of anaplasmosis of cattle. Although dogs seem to be the major host, this tick attaches to other animals and occasionally to man. It frequently invades homes and becomes a nuisance. A generation may be completed in less than two months in heated buildings or during summer months, provided that there is an abundance of food.

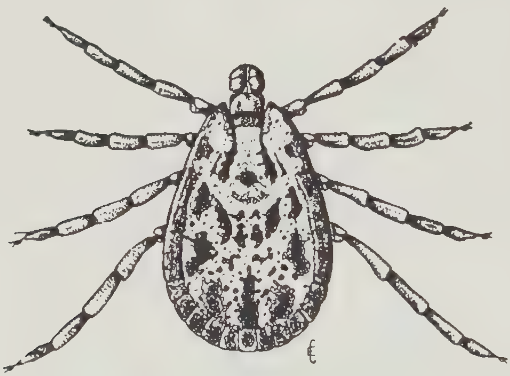


Fig. 562. The Rocky Mountain wood tick, *Dermacentor andersoni* Stiles. (Mont. Agr. Exp. Sta.)

Rocky Mountain Wood Tick, *Dermacentor andersoni* Stiles (Fig. 562), is a blood-sucking pest of both wild and domesticated animals, and frequently attacks man. Besides the irritation from the bites, this species transmits the rickettsial organisms causing spotted fever and the bacteria causing tularemia in man and other animals.

This tick is found in brushy areas of the Rocky Mountain states, from British Columbia to Arizona and New Mexico, and in isolated spots of the Pacific Coast states. The Bitter Root Valley of Montana has been the focal area endemic to the highly fatal spotted fever, but the disease

is now present throughout the United States. Tularemia is likewise widely distributed in the United States.

The life cycle of this tick is much the same as that described for the American dog tick, except that only nymphs and adults overwinter successfully. Only adults feed on man and large animals; the larvae and nymphs feed on smaller mammals. Immunity to spotted fever can be induced by means of the vaccine injections developed by the United States Public Health Service with seasonal "booster shots."

Winter Tick, *Dermacentor albipictus* (Pack.), is common in the Southwest, Midwest, and north central states. It is found most often on horses and may attack cattle. The life cycle is similar to those species previously described.

Gulf Coast Tick, *Amblyomma maculatum* Koch, occurs along the Gulf of Mexico. It attaches to all farm animals but is more common on cattle, especially about the ears. In midsummer, as many as 100 may be found on a single animal; in addition to inflammation, their bites serve as places of entry for screw-worms. The life history is the same as for the cattle tick.

Lone Star Tick, *Amblyomma americanum* (L.), is most abundant in the southwestern states. It is recognized by the white spot on the back of the adult and attaches to any part of the body of man, all kinds of livestock, and many wild animals, especially deer.

Tick Control. Climatic factors are probably the most important in natural control of ticks.

The elimination of the cattle tick population from most of the United States was achieved by dipping all animals in arsenical materials on a state-wide basis, every two weeks from March to November, and placing them in pastures known to be tick-free. The more recently developed chemicals are much more effective and are of great help in destroying all kinds of ticks. Approved chemicals for tick control on lactating dairy animals are sprays containing 0.25% Ciodrin, 0.1% pyrethrins plus 1% piperonyl butoxide, or 4 ounces of 5% WP rotenone per gallon of water. The previously mentioned chemicals, plus 0.25% coumaphos, 0.15% dioxathion, 0.05% lindane, 1% carbaryl or trichlorfon, 0.75% ronnel, 0.5% malathion or toxaphene, are approved for application to beef animals and sheep. If dipping is the more appropriate treatment method, the concentration of chemical in some instances is slightly different. Follow the directions on the package.

In some places area treatment to eliminate ticks is desirable. DDT, chlordane, dieldrin, or toxaphene at 1 to 3 pounds per acre, or lindane at $\frac{1}{2}$ to 1 pound per acre are the recommended chemicals. Do not allow animals to graze in such treated areas.

Ticks may invade homes, the brown dog tick being most common. They may be eliminated by sprays of 1% diazinon or ronnel or 2% malathion, in case they are resistant to the standard remedies of 2% chlordane, 5% DDT, or 1% lindane.

Persons working in tick-infested areas may find repellents such as diethyl toluamide, dimethyl phthalate, dibutyl adipate, benzyl benzoate, or N-butyl acetanilide of protection value. Should ticks successfully attach to man they can be stimulated to disengage their mouthparts by applying chloroform, turpentine, alcohol, or a hot needle to their body. After removal, sterilize the wound with tincture of iodine, merthiolate, or mercresin.

References: *U.S.D.A. Cir.* 478, 1938; *Leaflet* 387, 1963; *Yearbook of Agriculture*, pp. 662–663, 1952; E–762, 1951; *Farmers' Bul.* 1057, 1932; *J. Econ. Ent.*, 43:698–701, 1950; 44:1025–1026, 1951; 45:889–890, 1952; 57:340–346, 1964.

EAR TICK

Otobius megnini (Dugès), Family Argasidae

This soft-backed tick is found primarily in the semiarid sections of southwestern United States, the Rocky Mountain and Pacific Coastal states, and in Mexico and South America.

It attaches itself deep in the ears of cattle, sheep, goats, dogs, horses, and many wild animals. Its blood-sucking habit causes irritation and annoyance, and the bites occasionally become infected with pus-forming bacteria, giving rise to a condition known as "ear canker." Animals heavily infested scratch their ears, producing wounds which attract screw-worm flies.

The life cycle is similar to that of other ticks. The young are covered with spines, giving rise to the common name "spinose ear tick." The spines do not occur on the adult and to our knowledge only the larval and nymphal stages are parasitic.

Control is accomplished by injecting $\frac{1}{2}$ ounce of 1% lindane-pine oil mixture into each ear with a rubber tipped oil can, or gently dusting deeply inside each ear with 0.5% coumaphos, 5% ronnel, or 5% malathion. Squeeze bottle dusters are available as applicators.

References: *U.S.D.A. Farmers' Bul.* 980, 1953; *Agr. Handbook* 290, 1965.

POULTRY LICE

Order Mallophaga

Lice constitute one of the important problems of the poultry raiser. At least a dozen species attack chickens and others occur on turkeys, ducks, geese, guineas, and pigeons.

Infested individuals appear droopy and pale of comb and wattles; they

lack appetite, and older birds fail to lay eggs. This is caused by the annoyance and irritation from the claws and bites of the lice, whose food consists of skin scales, scabs, or blood clots which form after they bite the skin with their chewing mouthparts.

Poultry lice live on the host throughout the year but are more abundant during the summer. Their eggs adhere to the feathers; the wingless nymphs, hatching from them, molt several times and become adults in a few weeks, with many overlapping generations occurring.

The chicken head louse (Fig. 563), *Cuclotogaster heterographa* (Nitzsch), is most injurious to young chicks. It occurs on the head at the base of the feathers or down, and passes readily from one chicken to another through contact.

The chicken body louse (Fig. 563), *Menacanthus stramineus* (Nitzsch), is most injurious to grown fowls and often affects young chicks. It is found directly on the skin of any part of the body but especially below the vent.

The shaft louse (Fig. 564), *Menopon gallinae* (L.), is much smaller than the body louse, which it otherwise resembles. It tends to cling to the feathers rather than to the skin of the bird but undoubtedly causes irri-

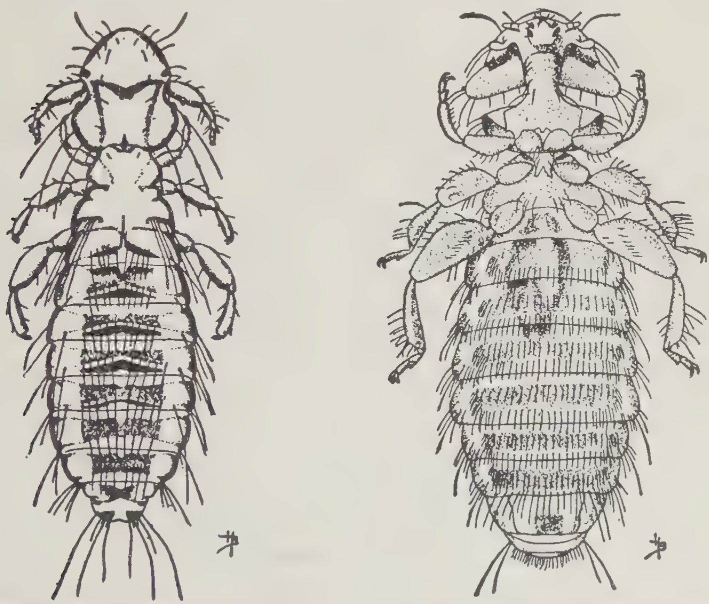


Fig. 563. The chicken head louse, *Cuclotogaster heterographa* (Nitzsch) (left), and the chicken body louse, *Menacanthus stramineus* (Nitzsch) (right). (U.S.D.A.)

tation. It is often the most common of the lice on chickens. Other chicken lice are the large chicken louse, *Goniodes gigas* (Tasch.), the brown chicken louse, *G. dissimilis* Denny, the wing louse, *Lipeurus caponis* (L.), and the fluff louse, *Goniocotes gallinae* (DeGeer) (Fig. 565). More species in the genus *Goniocotes* may invest Chickens.

Besides the chicken body louse and the shaft louse, there are two species that are quite specific to turkeys. These are the large turkey louse, *Chelopistes meleagridis* (L.), and the slender guinea louse, *Lipeurus numidae* (Denny). The latter species may also attack peafowl.

Lice on geese and ducks are seldom present in sufficient numbers to cause noticeable annoyance. The common species are the goose body louse, *Trinoton anserinum* (F.), and the large duck louse, *Trinoton querquedulae* (L.). Young ducks of geese may become infested with chicken head lice if closely associated with chickens.

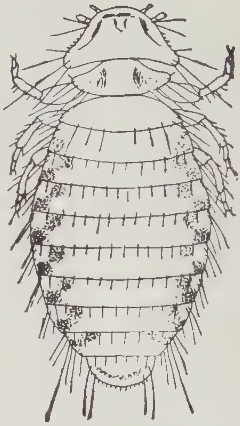


Fig. 564. The shaft louse, *Menopon gallinae* (L.). (U.S.D.A.)

Lice of the genera *Menacanthus*, *Menopon*, and *Trinoton* belong to the family Menoponidae; those in the genera *Chelopistes*, *Cuclotogaster*, *Goniocotes*, *Goniodes*, and *Lipeurus* belong to the family Philopteridae.

Poultry lice may be controlled by applying undiluted 40% nicotine sulfate to the top surface of the perches by spraying or with a paint brush just before the fowls go to roost. The fumes generated by the body heat of the birds kill the lice for about a three-day period. Head lice are least affected. Since the louse eggs are not killed, repeat the treatment frequently. Roost paints containing 3% malathion have also proved to be effective louse killers. Dusting the birds, roosts, litter, and nests with 1% rotenone or 4% malathion at the rate of 1 pound per 100 birds gives good louse control. Other approved dusts for treating the birds are 0.5% coumaphos and 5% carbaryl; coumaphos may also be used to treat the litter. The carbaryl treatment may be repeated in four weeks if needed, but not more often. Providing dust-bath boxes containing 1% rotenone, 4% malathion, 5% carbaryl, or 0.5% coumaphos allows the birds to treat themselves. Spray formulations of the insecticides are sometimes substituted for the dusts. Do not contaminate feed or water with these chemicals.

Dimethoate, dioxathion, naled, and ronnel have shown promise as poultry lousicides.

References: *U.S.D.A. Farmers' Bul.* 1652, 1953; *Leaflet* 474, 1966; *J. Econ. Ent.*, 48: 141–146, 1955; 54:1114–1117, 1961.

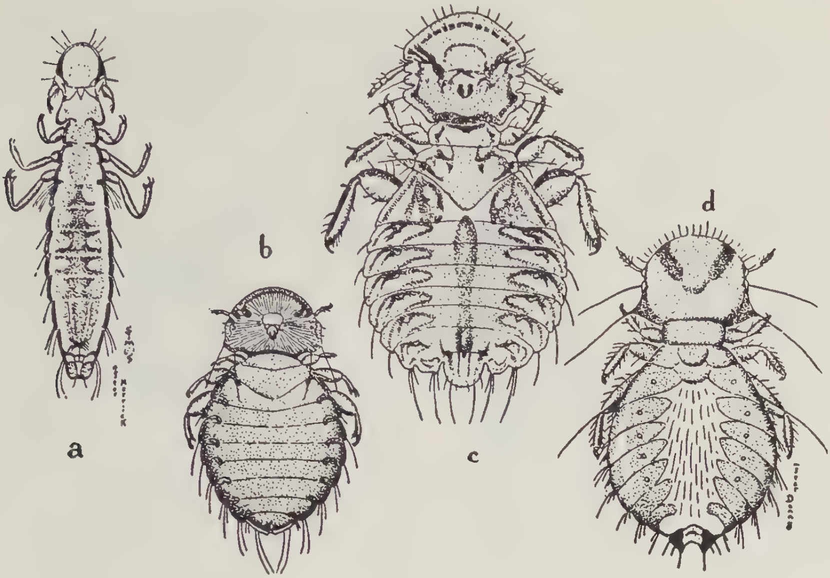


Fig. 565. *a*, the wing louse, *Lipeurus caponis* (L.); *b*, the fluff louse, *Goniocotes gallinae* (DeGeer); *c*, the large chicken louse, *Goniodes gigas* (Tasch.); *d*, the brown chicken louse, *G. dissimilis* Denny. (Mote, Ohio. Agr. Exp. Sta.)

MISCELLANEOUS POULTRY PESTS

Chicken Mite, *Dermanyssus gallinae* (DeGeer), sucks blood from fowls at night and remains secluded during the day in and about the nests and perches. Rarely do any occur on the fowls during the day. When numerous, these pests greatly reduce the vigor of a flock which is reflected in low weight gains and in low egg production. The red and gray mites are just large enough to be seen without a magnifying glass (Fig. 566).

The mite is inactive during cold weather but continues to breed the year around where warm weather prevails. It is always most abundant in summer. The white eggs are laid in the same place where hiding occurs during the day, and a generation may occur as often as every seven to ten days (Fig. 567).

Effective control is accomplished by thoroughly cleaning the poultry house and then treating all probable hiding places with one of the chemicals recommended for poultry louse control, with the exception of rotenone which is ineffective. Spray formulations give more satisfactory control of this pest. Anthracene oil diluted with an equal quantity of kerosene and applied to the perches, perch supports, and nests is an older recommended treatment which has merit.

Northern Fowl Mite, *Ornithonyssus sylviarum* (C. and F.), also called the feather mite, has been quite injurious in northern areas of the United

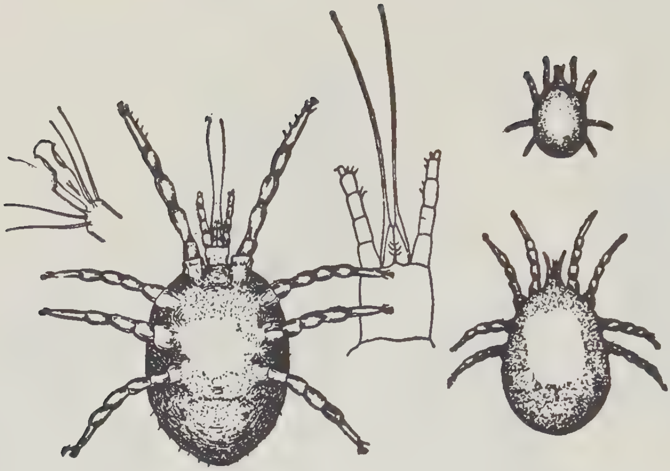


Fig. 566. The chicken mite, *Dermanyssus gallinae* (DeGeer); (top left) enlarged foot; (center) enlarged head of female. (U.S.D.A.)

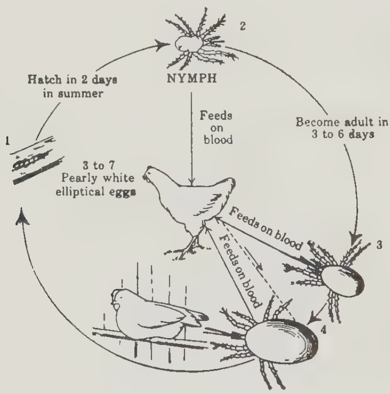


Fig. 567. Life cycle of the chicken mite, *Dermanyssus gallinae* (DeGeer). (U.S.D.A.)

States. This mite closely resembles the chicken mite but differs in that it breeds among the feathers and spends its entire life cycle on the host. The presence of the mites is often first noticed on the hens' eggs, and examination of the chickens will reveal groups of mites, their eggs and excrement among the feathers, especially about the tail. Their presence causes annoyance, loss of blood, and lack of thrift in the birds attacked.

This pest may be introduced into poultry flocks by infested English

sparrows, pigeons, and mice. Destroying their nests in the vicinity of poultry houses and eradicating mice are recommended procedures.

Control measures for the northern fowl mite are the same as given for poultry lice (p. 624), with the exception of rotenone. Treatment of the birds, litter, and nests is necessary. Dusting sulfur has given excellent control when applied to the litter at a dosage of 4 pounds per 100 square feet. Dust baths of sulfur (in addition to those suggested for poultry lice) are recommended. All roosters should be given individual treatment because they do not use dust baths.

Depluming Mite, *Knemidokoptes gallinae* (Raill.), is an itch mite that lives at the base of the feathers of fowls and pigeons (Fig. 568). It produces intense itching causing the fowls to pull out their feathers. If the stumps are examined soon after breaking of the quill, they will be found surrounded by skin scales and often encrusted. For complete control, treat the entire flock by dusting with sulfur, as suggested for northern fowl mite, or dipping in a mixture consisting of 4 ounces of sulfur, 4 ounces powdered soap, in 2 gallons of water. Dipping should be done on warm sunny days.

Scaly Leg Mite, *Knemidokoptes mutans* (R. and L.), attacks both wild and domesticated fowls and is the cause of a condition sometimes described as leg mange. The minute mites (Fig. 569) burrowing under the scales cause irritation, resulting in raised scales, exudation of blood and lymph, and the formation of a powdery substance. In severe cases the joints become so inflamed that the birds are lame and scarcely able to walk. This mite occasionally attacks the comb and wattles. Isolate the affected birds, and dip the feet and legs into crude oil, kerosene, or

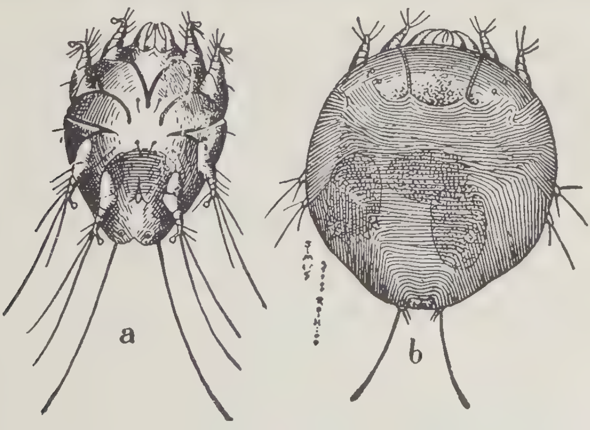


Fig. 568. The depluming mite: *a*, adult male (× 114); *b*, adult female (× 108). (Mote, Ohio Agr. Exp. Sta.)

Fig. 569. Scaly leg mite: male (left), female (right), infested leg of fowl, above, and mite in burrow in skin, below. (Mote, Ohio Agr. Exp. Sta.)

another light oil. Usually one application is sufficient to bring about control. To prevent spread of the mites, treatment of the perches with oil is also recommended.

Sticktight Flea, *Echidnophaga gallinacea* (Westwood) (Fig. 570), is a pest well known in many parts of the South and is occasionally present in the northern sections of the country. It attaches itself in one place and remains there instead of hopping actively, as do other fleas.

When abundant they reduce egg production, often kill young chickens and sometimes even mature fowls by their blood-sucking habit. They tend to congregate in clusters on the comb, wattles, and around the eye. This species also attacks dogs, cats, horses, man, and wild birds.

Effective control can be accomplished by area treatment of all grounds, as well as the litter, roosts, nests, and walls of the poultry house. Malathion is perhaps the best material to apply in all these places. Treat with 4% dust at the rate of 1 pound per 20 square feet, or use a spray at 0.5% concentration. Carbaryl, as suggested for poultry lice control, should also check flea populations. Breeding areas outside the houses may be treated with DDT, chlordane, or methoxychlor. All these treatments are directed toward killing flea larvae. Infested birds should be given individual treatment by applying derris or cubé powder in vaseline to affected parts, being careful not to get the ointment in the eyes of the bird.

Other species of fleas that attack poultry and are known to be present in parts of this country are the European chicken flea, *Ceratophyllus gallinae* (Schr.), and the western chicken flea, *Ceratophyllus niger* Fox.

Fowl Tick, *Argas persicus* (Oken), is another ectoparasite of poultry which is common in the southwestern states but is little known elsewhere, except occasionally in Florida. It is red or brown, sometimes with a tinge

Fig. 570. The sticktight flea, *Echidnophaga gallinacea* (Westwood). (U.S.D.A.)

Fig. 571. The fowl tick, *Argas persicus* (Oken); upper and lower surfaces of adult female. (U.S.D.A.)

of blue, which suggests the name "blue bug" by which it may be known locally (Fig. 571).

When fully grown this tick may be $\frac{1}{5}$ to nearly $\frac{1}{2}$ inch long. The females deposit many brown eggs in masses about poultry houses. Hatching occurs in ten or more days, and the six-legged nymphs or seed ticks attach to poultry at night, feed until engorged, which may require three to ten days, and then drop off, molt, and gain the fourth pair of legs. Thereafter, the ticks attack poultry only at night after they have gone to roost. Their painful bites and blood-sucking habits greatly reduce the vitality and egg production of a poultry flock. Also, they are known to be carriers of the organisms causing fowl spirochaetosis, prevalent in other parts of the world.

Effective control depends on killing the ticks outside the poultry houses to prevent them from reaching the birds, and/or treating inside the houses to kill the ticks that leave the birds after engorgement. Chemicals recommended for use outside the houses are 2% chlordane and 5% DDT or toxaphene; for inside use apply 3% malathion, 2% carbaryl, or 0.3% naled. Do not treat litter with carbaryl and do not contaminate water or feed with any of these chemicals.

References: *U.S.D.A. Farmers' Bul.* 1652, 1953; *Leaflets* 382, 1955; 383, 1964; *J. Econ. Ent.,* 45:748–749, 1952; 47:942–944, 1954; 54:1212–1214, 1961.

HOUSE FLY

***Musca domestica,* L., Family Muscidae**

Found throughout most of the world, house flies are more abundant wherever man makes his abode. They have been known during all periods

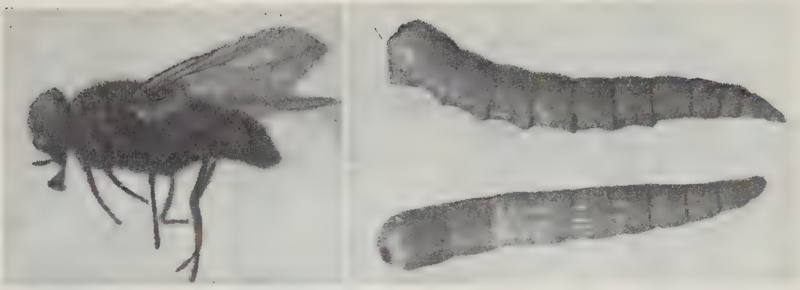


Fig. 572. The house fly, *Musca domestica* L.; adult and larvae.

Fig. 573. Egg masses of the house fly. (U.S.D.A.)

of time for which we have records. Besides being annoying to man and other animals, house flies may serve as carriers of the organisms causing several important diseases: conjunctivitis, poliomyelitis, typhoid fever, tuberculosis, anthrax, leprosy, cholera, diarrhea, and dysentery. They also serve as intermediate hosts for the helminths, of which three species of tapeworms parasitic on poultry and three species of nematodes parasitic on horses, mules, and donkeys are the most important.

The adult is a typical fly with sucking or lapping mouthparts. The larvae or maggots are tapered and creamy white (Fig. 572). Female flies deposit two to twenty-one egg masses (Fig. 573), each containing about 130 white eggs, in manure or fermenting vegetable matter. Any kind of animal excrement may serve as a breeding medium if it is moist and of the proper temperature. Hatching takes place in ten to twenty-four hours

and the resulting maggots become fully grown in three to seven days, crawl to the margins of the breeding material, and change to dark brown puparia, from which adults emerge three to six days later. In the laboratory, at a temperature of 80° F., the entire life cycle from egg to adult requires ten to twelve days.

House fly populations are checked or destroyed by sanitation, screening, trapping, baiting, aerosols, and residual and space sprays of insecticides.

Elimination of breeding areas by daily removal and scattering of manure on the fields is recommended wherever practical. Proper wrapping, temporary storage, and disposal of garbage is also important in the prevention of fly breeding. Treating manure or other breeding materials with diazinon, malathion, ronnel, DDVP, or dimethoate will give good kill of larvae. Do not use diazinon in poultry houses.

Screening homes and buildings with 16-to-18-mesh screen wire is a means of preventing annoyance from flies and other insects. Traps of various types have been devised and are of value in reducing fly populations. Most of them employ a bait of ripened fruit, syrup, cheese, or milk, which attracts the flies into an inescapable chamber or electrocutor. Tanglefoot ribbons are of value in reducing fly populations in screened buildings.

Poisoned baits, either liquid or dry, are very common for controlling flies, especially those which become resistant to the chlorinated hydrocarbon insecticides, particularly DDT. The most effective baits contain organic phosphorus insecticides, combined with sugar or syrup as the attractant. Some preference for the dry baits has been indicated because of convenience in handling. Many commercial formulations are available, and the directions given on the package should be followed when using these baits. An effective bait formulation consists of 2 teaspoonfuls of 25% malathion wettable powder and 2 teaspoonfuls of sugar in 1 ounce of water. Mix this with $\frac{3}{4}$ cup of corn meal, allow to dry, and place in a shaker-type can. Other organic phosphorus compounds that have performed well as baits are DDVP, diazinon, ronnel, trichlorfon, and naled. An old standard bait that will kill both normal and resistant strains of flies consists of 3 teaspoonfuls of commercial 40% formalin in a quart of milk, to which a little sugar or syrup has been added. All fly baits are highly poisonous and care must be exercised in handling them.

Commercial fly spray solutions or aerosol bombs containing DDT, methoxychlor, lindane, organic thiocyanates, DDVP, or ronnel, plus synergized pyrethrins are effective for controlling flies in enclosed places. Space sprays containing some of these chemicals plus Lethane 384 have been effective in barns where flies have developed resistance to DDT and related compounds.

Residual sprays of dimethoate, ronnel, malathion, diazinon, trichlorfon, lindane, fenthion, Ciodrin, naled, DDVP, or methoxychlor may be applied to the walls and other areas inside and outside barns and other buildings where flies congregate. Animals must not be present during spraying and contamination of foods, feed troughs, water fountains, and milking equipment must be avoided. Surfaces should be wetted to the point of run-off. Places where flies rest at night are indicated by fly excrement; these areas should be thoroughly saturated with the insecticide. Cloth ribbons, strings, or strips of screen wire dipped in any of the residual insecticide solutions and then suspended in fly-infested buildings will serve as resting places and give remarkable control of flies. DDVP impregnated plastic strips are approved for use in milk processing rooms and other enclosures with little air movement. Dimetilan impregnated bands have given almost full season control in dairy barns.

Continuous use of the same insecticide results in populations of house flies that become resistant or can tolerate that chemical. Changing to an entirely different chemical and inauguration of bait sprays have helped to counteract the problem.

Introduction of the following species of larval and pupal parasites of the house fly gives promise of a successful biological control effort in some regions: *Muscidifurax raptor* Girault, and Sanders, *Spalangia endius* Walker, and *Stilpnus anthomyidiperda* (Viereck).

References: *U.S.D.A. Leaflet* 390, 1965; EC-29, 1954; L. S. West, *The House Fly*, Comstock Publishing Assoc., Ithaca, N.Y., 1951; *J. Econ. Ent.*, 46:172, 1953; *Ohio Ext. Bul.* 473, 1966.

The cluster fly, *Pollenia rudis* (F.), is slightly larger than the house fly, more sluggish, with the larval stages parasitic on earthworms and possibly

Fig. 574. The cluster fly, *Pollenia rudis* (F.). (Howard.)

other hosts. The adults (Fig. 574) invade houses in autumn, often appearing in the attic, or other places offering shelter such as the space between windows and storm sash. Control measures are directed only against the adults when they become abundant in houses. Use aerosols of DDT plus pyrethrins or residual sprays of DDT or chlordane.

MOSQUITOES

Order Diptera, Family Culicidae

Many species of mosquitoes attack man and other animals; some of them are widespread, others rather local in their distribution. Common ones are the yellow-fever mosquito, *Aedes aegypti* (L.); the salt-marsh mosquito, *A. sollicitans* (Wlkr.); the brown salt-marsh mosquito, *A. cantator* (Coq.); the California salt-marsh mosquito, *A. squamiger* (Coq.); the black salt-marsh mosquito, *A. taeniorhynchus* (Wied.); the tree-hole mosquito, *A. triseriatus* (Say); the northwest coast mosquito, *A. aboriginis* Dyar; the common malarial mosquitoes, *Anopheles quadrimaculatus* Say, *Anopheles punctipennis* (Say), and *Anopheles freeborni* Aitken; the northern house mosquito, *Culex pipiens* L.; the southern house mosquito, *Culex quinquefasciatus* Say; and species of *Mansonia* and *Psorophora*.

Mosquitoes are important pests since they cause annoyance and discomfort; they may be responsible for reducing property values in heavily infested areas; they also transmit organisms causing malaria, encephalitis, yellow fever, dengue, and filariasis. The species, *Culex tarsalis* Coq., *Aedes nigromaculis* (Ludl.) and *A. dorsalis* (Meigen), have also been shown to be vectors of equine encephalomyelitis. The female mosquito pierces the skin and injects saliva at the time of feeding, which is responsible for the irritation that follows. Blood taken from man or other animals infected with disease-producing organisms in turn infect the mosquito, which transmits them to future hosts (Figs. 575 and 579).

The life cycles of mosquito species vary. Many of them overwinter as eggs, others as larvae or adults. In the North, the fertilized females of *Culex* and *Anopheles* species survive the winter, in warmer regions breeding occurs the year around. *Aedes* and *Psorophora* normally pass the winter in the egg stage. *Culex* mosquitoes deposit masses of elongated eggs on end, which float on the water surface like a raft, whereas *Anopheles* and *Aedes* eggs are laid singly. Those of *Anopheles* float on the water, and those of *Aedes* are attached to moist objects near the water surface (Fig. 576). Eggs of *Aedes* are able to withstand long periods of drying and on being immersed in water hatch in several minutes. Usually a two- or three-day incubation period is required for *Culex* and *Anopheles* eggs. Among the blood-sucking mosquitoes, a blood meal is generally necessary for egg production.

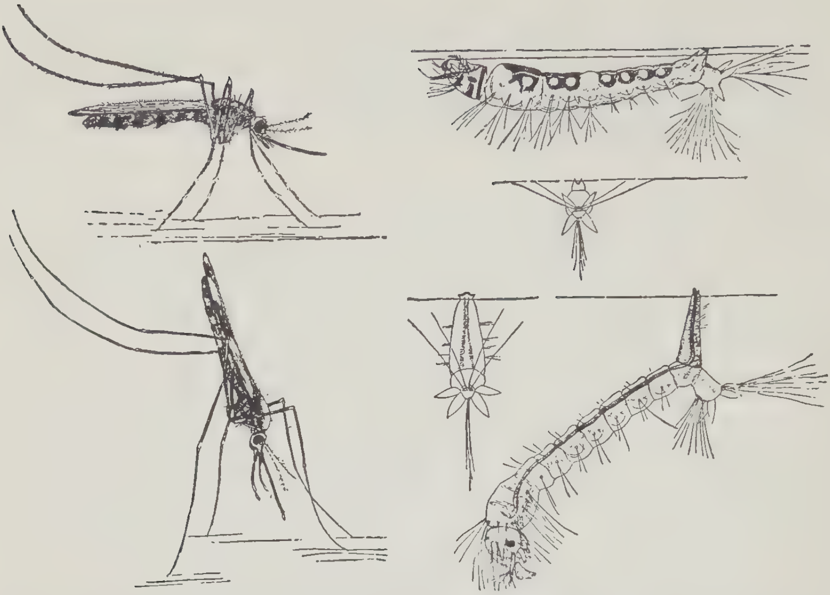


Fig. 575. Feeding positions of mosquito adults and larvae: (upper left) adult *Culex,* (lower left) adult *Anopheles,* (upper right) *Anopheles* larva, (lower right) *Culex* larva. (U.S.D.A.)

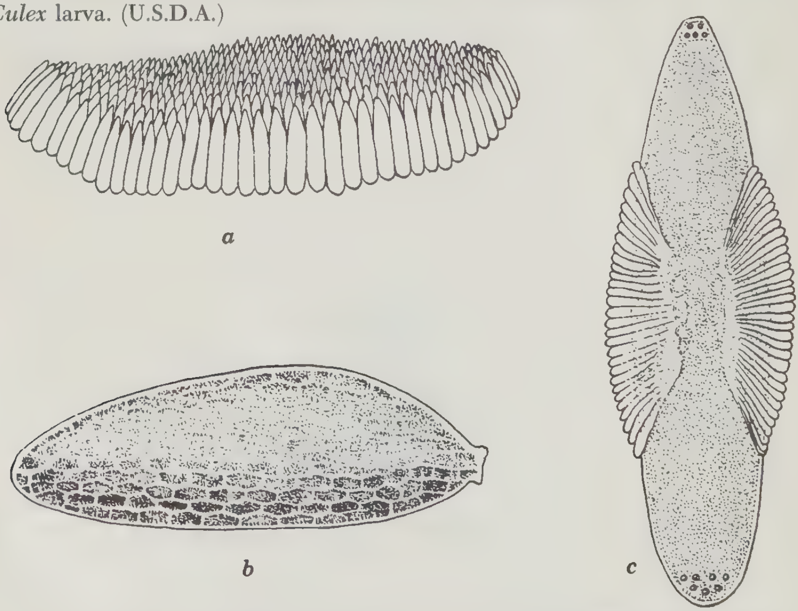


Fig. 576. Eggs of mosquitoes: *a,* egg raft of *Culex restuans* Theob.; *b,* egg of *Aedes taeniorhynchus* (Wied.); *c,* egg of *Anopheles quadrimaculatus* Say, showing floats. (Howard, Dyar, and Knab.)

The larvae of all mosquitoes are aquatic and, although possessing tracheal gills, must come to the surface for additional air obtained by means of a respiratory tube that projects through the surface film of water (Fig. 575). This tube varies in length according to the species; it is much shorter in *Anopheles* than in *Aedes* and *Culex*. The larvae move about by a series of spasmodic motions, feeding on protozoa, bacteria, algae, and other microorganisms. *Anopheles* larvae are primarily surface feeders and lie parallel to the water surface, whereas *Culex* and *Aedes* feed below the surface and lie at an angle of 45° when at rest (Fig. 575). The period of development requires several days and the larval skeleton is shed four times before the pupal stage appears.

The pupae have two short respiratory tubes on the thorax (Fig. 577), and take no food, but they can swim about in the water. After a few days in this stage the adults emerge, making a total period from egg to adult of ten to fourteen days at temperatures of 80° F. The length of the life cycle is influenced by climatic factors, usually a single to many generations developing each year depending on these factors and the species of mosquito.

Adult mosquitoes are small two-winged flies, the body, legs, and wings of which are covered with tiny scales. The feeding positions and head characters of adult females of *Culex* and *Anopheles*, are shown in Figs. 575 and 578. Male mosquitoes do not suck blood but subsist on the nectar of flowers, fruit juices, and water. If none of these is available, death soon follows. The males are distinguished from females by their smaller size, more bushy antennae, and more prominent palpi.

Control of mosquitoes is accomplished in various ways. Where feasible, elimination of breeding places by drainage, filling, or sanitation is an effective measure. Frequent inspection of the premises should be made to see that eave troughs, tin cans, bottles, jars, barrels, or other objects are

Fig. 577. *Culex pupa.* (Howard, U.S.D.A.)

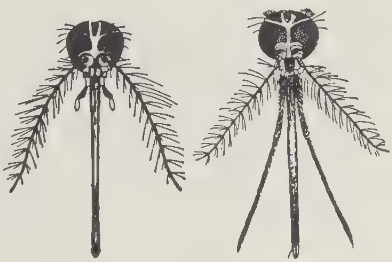


Fig. 578. Head of female *Aedes* mosquito (left) compared with that of *Anopheles* (right). (Ky. Agr. Exp. Sta.)

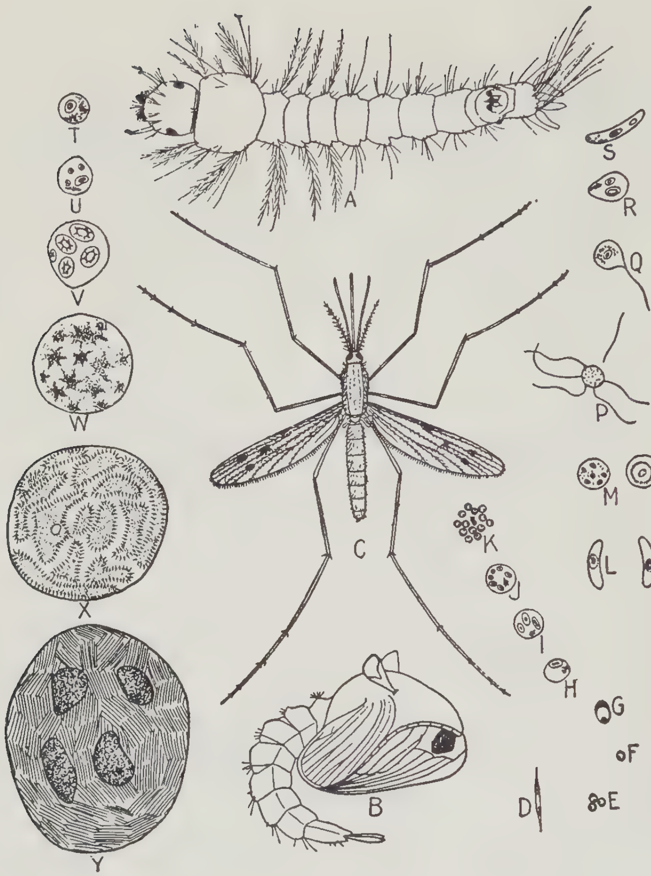


Fig. 579. The malaria mosquito, *Anopheles* sp.: *A*, larva; *B*, pupa; *C*, adult; *D* to *Y*, stages in the development of the protozoan, *Plasmodium*. (N. J. Agr. Exp. Sta.)

not serving as breeding spots. The introduction of certain species of fishes has proved of value in the control of mosquitoes in permanent ponds, pools, and salt marshes.

Application of larvicides by hand or power equipment has given excellent control, but care must be exercised because of the danger of killing fish and other aquatic animals in some habitats. Dust formulations are less toxic to wildlife than oil emulsions or solutions, but they are also less effective in control, except for the surface feeders. Paris green at the rate of 1 to 2 pounds per acre is effective in killing anopheline larvae. Kerosene or fuel oil (No. 2) alone or in combination with 0.007% pyrethrins at the rate of 20 to 30 gallons per acre has proved to be a good larvicide. Abate, DDT, TDE, methoxychlor, chlordane, aldrin, dieldrin, heptachlor, lindane,

toxaphene, fenthion, malathion, parathion, or EPN, in fuel oil, methylated naphthalenes, similar type solvents, or in emulsions, at 0.03 to 0.5 pounds per acre have also given excellent control of larvae. The exact dosage will depend on the area to be treated and the chemical used. Higher dosages are required for longer protection. In Alaska large areas treated with 0.3 pound of DDT per acre had much lower populations of mosquitoes than adjacent untreated areas, even a year after the sprays were applied. In irrigated areas pretreatment of the dry soil, before flooding, with 1 to 3 pounds of DDT or 1 pound of dieldrin per acre, has controlled mosquitoes for a period of one to three months. Larviciding rice fields is often necessary to prevent mosquito breeding.

For killing adults in enclosed places use aerosols or space sprays containing DDT, methoxychlor, dichlorvos, naled, malathion, or synergized pyrethrins. Residual sprays of 5% DDT or methoxychlor, 2% chlordane, 3% fenthion or malathion, 0.5% dichlorvos, dieldrin, heptachlor or lindane may be applied to walls of buildings, catch basins or other places where mosquitoes rest. Fogging out-door areas with solutions of DDT, methoxychlor, naled, chlordane, heptachlor, lindane, dichlorvos, fenthion, malathion, or synergized pyrethrins, when there is little wind reduces adult populations. For better kill in such areas, treat the vegetation with DDT, dieldrin, lindane, or fenthion.

Screening houses is necessary for protection against adults and 18-mesh wire is required to prevent some individuals of *Aedes aegypti* from entering. Mosquito netting gives protection in camp areas or other places not properly screened.

There is no known substance that will give complete freedom from mosquito attack for more than several hours. Repellents are applied to the exposed skin and, if necessary, to clothing, the better materials being dimethyl phthalate, 2-ethyl-1,3-hexanediol, dimethyl carbate, diethyl toluamide, or a mixture containing six parts dimethyl phthalate and two parts each of 2-ethyl-1,3-hexanediol and indalone. These repellents are solvents for paints, varnish, and plastics, so care must be excercised in their use. Most of them cause some irritation if accidentally applied to mucous membranes. For relief from itching after being bitten, apply 5 to 10% benzocaine in ethyl alcohol, or Thephorin ointment.

References: *U.S.D.A. Misc. Pub.* 336, 1939; *Agr. Handbooks* 152, 1959; 173, 1960; 120, 1964; *Home & Garden Bul.* 84, 1962; *Conn. Agr. Exp. Sta. Bul.* 632, 1960; *J. Econ. Ent.*, 42:586–590, 1949; 43:350–353, 1950; 44:428–429, 1951; 45:712–716, 1952; 46:164, 1953; 47:818–824, 1954; 56:58–60, 834–835, 1963.

CHIGGER MITES

Order Acarina, Family Trombiculidae

A number of species of mites are troublesome to man and other animals, among them the chiggers or redbugs. The most numerous and widely

distributed species is *Trombicula alfreddugèsi* (Oudemans), which occurs throughout the United States east of the Rocky Mountains. It has also been reported from Canada, California, Arizona, Mexico, Central America, South America, and neighboring islands. Related species are *T. splendens* Ewing, which has a similar but more restricted range, and *T. batatas* (Linn.), a tropical species found only in the warmer, southeastern part of the United States and Central and South American countries. Distinguishing characteristics of these three species of chiggers are shown in Fig. 580.

Contrary to popular belief, chiggers do not burrow into the skin; they only insert their mouthparts, usually in a skin pore or hair follicle, and begin feeding. On man they are found especially in regions of the body with tight-fitting clothing. The salivary juices secreted by the chiggers cause severe irritation accompanied by intense itching. This results in scattered red blotches of various sizes, with frequent secondary infection. Persons exposed repeatedly may develop immunity to the irritation.

Chiggers are found where vegetation is abundant, such as shaded areas, high grass or weeds, fruit orchards or berry patches. However, they may become serious pests in relatively dry areas, such as lawns, golf courses, and parks. They are tiny and not easily seen, and since their bites may not be felt for several hours after exposure it is difficult to know the exact location of infestation. To determine such an area, place a piece of black cardboard edgewise on the ground where chiggers are suspected. If present, in a few minutes tiny yellow or pink mites will be seen moving rapidly over the cardboard and accumulating on the upper edge. They may also be detected on black polished shoes.

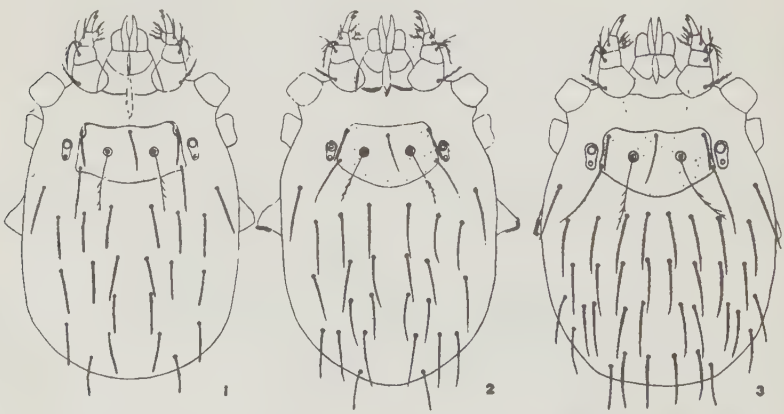


Fig. 580. Dorsal views (legs absent) showing distinguishing characters of three species of chiggers attacking human beings: 1, *Trombicula alfreddugèsi;* 2, *T. splendens;* 3, *T. batatas.* (Courtesy of Dale W. Jenkins.)

Chiggers pass the winter as adults near or slightly below the surface of the soil. In the spring they become active and deposit their eggs, varying from a few to as many as fifteen per day. These hatch into six-legged individuals called "larvae," the only stage that attacks man. After engorgement, which may require from one to several days, the larvae drop off, transform into eight-legged nymphs, and finally into the adult stage. Both nymphs and adults are said to feed on eggs of springtails, isopods, and mosquitoes. Adult female chiggers have lived over 1 year and have produced offspring throughout that period. Repeat generations occur in warmer climates, whereas only two or three develop each season in the North.

Treatment of infested areas with chlordane or toxaphene at 2 pounds, or lindane at 0.25 pound of actual toxicant per acre provides a high degree of control for 1 to 2 months. Emulsion sprays usually give the best results, but wettable powder sprays and dusts have been quite satisfactory. The amount of various formulations of chlordane or toxaphene required to treat an acre or an area of 1000 square feet is indicated in the following table.

Formulation	Acre	1000 Square Feet
45%–48% emulsifiable	2 quarts	3 tablespoonfuls
72%–75% emulsifiable	1 quart	5 teaspoonfuls
40% wettable powder	5 pounds	8 tablespoonfuls
50% wettable powder	4 pounds	6 tablespoonfuls
5% dust	40 pounds	1 pound

The volume of water in the dilutions will depend on the type of spraying equipment used. Lindane as a 1% dust should be applied at 25 pounds per acre or 1 pound per 1000 square feet.

To prevent chigger attachment when going into probably infested areas, apply diethyl toluamide, dimethyl phthalate, dibutyl phthalate, dimethyl carbate, 2-ethyl-1,3-hexanediol, benzyl benzoate or sulfur dust to the clothing and also to the body, particularly to the legs, ankles, cuffs, waist, and sleeves. A thorough soapy bath soon after exposure will also be of help.

After itching begins some relief can be secured by treating the affected spots with the following formula which your druggist can prepare:

benzocaine, 5%
methyl salicylate, 2%
salicylic acid, 0.5%
ethyl alcohol, 73%
water, 19.5%

Apply the material to each welt with a piece of cotton or facial tissue. Repeat the treatment as often as necessary.

References: *U.S.D.A. Bul.* 986, 1921; *Leaflet* 403, 1963; *Am. J. Hygiene*, 48:22–35, 1948; *Ann. Ent. Soc. Amer.*, 42:289–318, 1949; *J. Econ. Ent.*, 55:22–33, 1962.

BED BUGS

Order Hemiptera, Family Cimicidae

Nearly world-wide in distribution the bed bug, *Cimex lectularius* L., is found primarily in human habitations, but it also attacks poultry, birds, mice, rats, guinea pigs, and rabbits. A related species, *Cimex hemipterus* (F.), is found in Florida and other tropical areas. The poultry bug, *Haematosiphon inodorus* (Dugès), is another species which commonly infests birds and poultry, and is found in some southwestern states and in Mexico. The swallow bug, *Oeciacus vicarius* Horvath, the bat bug, *Cimex pilosellus* Horvath, and the European pigeon bug, *Cimex columbarius* Jenyns, are other related species.

The bed bug *C. lectularius*, does most of its blood-sucking at night, and the bites are usually painless when inflicted. However, inflamed welts develop afterwards, along with severe itching caused by the injection of salivary juices during the feeding. The adult (Fig. 581) is a red-brown, wingless (except for vestiges) insect, slightly more than $\frac{1}{4}$ inch in length, with a more or less flattened body when unfed but swollen and elongated when engorged with blood. Under favorable conditions the adult female

Fig. 581. The bed bug, *Cimex lectularius* L. (Courtesy of Can. Dept. Agr.)

lives from two to ten months and deposits about 200 white eggs at the rate of three or four per day. Because of a sticky substance these adhere to the bedding or other objects in the infested area. At temperatures of 70° F. or above, hatching occurs in six to seventeen days, and the tiny nymphs molt five times before reaching the adult stage. Four to six weeks are required for completion of the life cycle, and there may be several generations in a year depending on the temperature and food supply. Development is greatly retarded as the temperature drops below 70° F., and no eggs are laid at 50° F. or lower. Newly hatched bugs may live several weeks without feeding during warm weather and for longer periods in cool weather. It is believed that adult bugs can live a year or longer without food.

It is not always necessary to see the bugs to detect their presence because of an offensive odor which is associated with them. At the beginning of an infestation the bugs are more likely to be found in the beds; as their numbers increase they spread to other parts of the room.

Bed bugs can be controlled by treating all the places where they hide. This includes the bed frames, mattress and springs, and, under heavy infestation, the baseboards, closets and other furniture in the room.

Satisfactory control has resulted from residual sprays of oil-base solutions containing 5% DDT or 2% chlordane. Where resistance to these compounds has developed, apply 2% premium grade malathion, 1% lindane, 1% ronnel, 0.5% diazinon or dichlorvos. In most instances where treatment of other areas is well done there will be little need for treating the mattress. Mattresses may be treated lightly with any of these chemicals at reduced concentrations where adults sleep, whereas only 0.2% synergized pyrethrins should be applied to mattresses where babies or children sleep. It is best to make all treatments in the morning so the solvent from the insecticides will be dissipated before nightfall. Dusts of these insecticides can be used for treating baseboards and closets. The common aerosol contains DDT, pyrethrins, and piperonyl butoxide, and is effective if sufficient insecticidal residue is deposited. Where sprays, dusts, or aerosols are not feasible, infestations may be eliminated by fumigating with methyl bromide or hydrogen cyanide (see p. 573).

References: *U.S.D.A. Leaflet* 453, 1959; *Conn. Agr. Exp. Sta. Cir.* 213, 1960.

FLEAS

Order Siphonaptera, Family Pulicidae

Fleas are widely distributed, blood-sucking, wingless insects whose bites cause irritation not only to man but also to cats, dogs, hogs, rabbits, rats, mice, and many other animals. They are important in the spread of the bacterial organism, *Pasteurella pestis* (L. and N.), causing bubonic plague,

Fig. 582. The human flea, *Pulex irritans* Linn. (Bishopp, U.S.D.A.)

and serve as intermediate hosts for the dog and rodent tapeworms that occasionally parasitize man.

The oriental rat flea, *Xenopsylla cheopis* (Roth.), is a vector in the spread of endemic or murine typhus from rats to man and is prevalent in the United States. Besides the oriental rat flea, common species of importance are the cat flea, *Ctenocephalides felis* (Bouché), the dog flea, *Ctenocephalides canis* (Curtis), and the human flea, *Pulex irritans* Linn. (Fig. 582).

All irritation to the hosts attacked is caused by the piercing-sucking adult stage. The adults are very narrow-bodied, dark brown, spiny insects (Fig. 583), with well-developed jumping legs. Their white eggs may be laid either on the animal or on the floor of infested buildings, but development of the apodal white larvae takes place only in dry organic material on the ground or floor. In two weeks or more the chewing larvae become fully grown and then spin cocoons in which they pupate, the adults emerging in the course of one or more weeks. A complete generation may be produced in a month during warm weather; the life cycle is greatly extended by low temperatures. In colder climates the winter may be passed in the pupal stage inside the cocoon. Recently emerged adult fleas may live for several months without food. This accounts for the fact that people with pets often find their homes heavily infested with fleas when they return after an extended absence.

Successful control of fleas involves treating the animals as well as the premises, particularly the place the animals sleep. The following insecticidal dusts have given satisfactory control of fleas: 5% DDT, 10% methoxychlor, 5% carbaryl, 1% lindane, 4% malathion, 1% rotenone, and 0.2% synergized pyrethrins. Cats groom themselves by licking; for this reason

Fig. 583. The dog flea, *Ctenocephalides canis* (Curtis); adult, larva, and egg. (Pettit, Mich. Agr. Exp. Sta.)

DDT should not be used to treat them. It is also best to avoid using DDT on puppies. Oil-base sprays containing 5% DDT or methoxychlor, 2% chlordane, 2% premium grade malathion, 0.5% lindane, diazinon, or dichlorvos are recommended for treating inside infested homes. It is best to treat after thoroughly vacuum cleaning the house and then destroying the material in the cleaner bag which usually contains all life stages of fleas. Infested lawns, hog barns, or other places may be treated with dusts or sprays using wettable powder or emulsion formulations. Elimination of rats, mice, and other rodents with poisoned baits is also necessary in a good flea control program.

References: *U.S.D.A. Leaflet* 392, 1964; *Yearbook of Agriculture*, p. 495, 1952; *Misc. Pub.* 500, 1943; *Am. J. Trop. Med.*, 31:252–256, 1951; *J. Econ. Ent.*, 46:598–601, 1953.

LICE ATTACKING MAN

Order Anoplura, Family Pediculidae

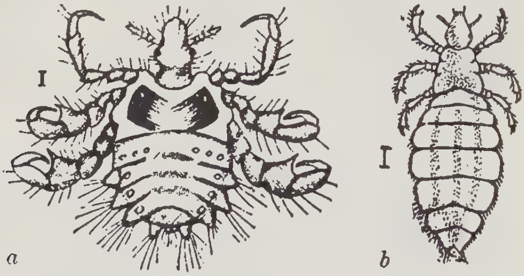
Three species of lice, the body louse, *Pediculus humanus humanus* L., the head louse, *Pediculus humanus capitis* DeG., and the crab louse, *Phthirus pubis* (L.), attack man the world over. All of them pierce the skin and suck blood, causing irritation, itching, and the development of objectionable welts. The body louse was the "grayback" of the Civil War and the "cootie" of World War I. It is a vector of the organisms causing epidemic typhus, trench, and relapsing fevers.

There is little morphological difference in the appearance of body and head lice; they are therefore normally differentiated on the basis of habits. Body lice are closely associated with clothing, laying their eggs in the seams and other protected places, and moving to the skin only to feed but still maintaining a hold on the cloth. Head lice (Fig. 584) live among the hairs and skin on the head and glue their eggs to the hairs. Head and body

lice can produce fertile offspring if crossbred and are therefore considered subspecies of a single species.

Crab lice (Fig. 584) are characteristic in appearance and frequent the pubic regions, the armpits, and sometimes the eyebrows. Their eggs adhere to the hairs of the host.

All human lice eggs hatch in about a week, and after three nymphal molts the adult stage is reached, the total period from egg to adult requiring three or four weeks.



a *b*

Fig. 584. *a,* the crab louse, *Phthirus pubis* (L.); *b,* the human head louse, *Pediculus humanus capitis* DeGeer. (U.S.D.A.)

Control measures consist of applications of 10% DDT dust, 1% lindane dust or MYL powder to the infested parts of the body and to the clothing. To be effective these powders should remain for twenty-four hours. MYL powder contains the following ingredients (in percentages):

Pyrethrins	0.2
N-isobutylundecyleneamide	2.0
2,4-dinitroanisole	2.0
Isopropyl cresols	0.25
Pyrophyllite	95.55

For body louse control additional measures are advocated, such as treatment of all clothing and bedding by steam sterilization, by dry heat at 150° F. for several hours, by washing in hot water, by exposure to deep-freeze temperatures, or by fumigation with methyl bromide or hydrogen cyanide. A 1% rotenone dust is of some merit in control, but repeated applications are required. Even when washed weekly, garments treated with a solution of 2% DDT in a volatile solvent will kill body lice for several weeks.

References: *U.S.D.A. Misc. Pub.* 606, 1946; *Yearbook of Agriculture,* pp. 487–491, 1952; *J. Econ. Ent.,* 46:524, 1953.

BLACK FLIES

Order Diptera, Family Simuliidae

The females of many species of tiny, hump-backed, black-bodied flies with transparent wings suck the blood of man, domesticated and wild animals. Besides the annoyance and irritation of their bites, some species are carriers of organisms causing disease. In Africa, Mexico, and Central American countries they are vectors of the parasite causing onchocerciasis.

Fig. 585. A black fly, the buffalo gnat, *Cnephia pecuarum* (Riley). (Garman, Ky. Agr. Exp. Sta.)

Fig. 586. Black fly larvae; *Simulium pictipes* Hagen, *S. venustum* Say, and *Cnephia pecuarum* (Riley). (Knowlton, Utah Agr. Exp. Sta.)

A few common forms are the buffalo gnat, *Cnephia pecuarum* (Riley) (Fig. 585), the turkey gnat, *Simulium meridionale* Riley, *S. vittatum*, Zetterstedt, *S. venustum* Say and *S. tuberosum* Lundström.

All species are more prevalent near regions where rapidly flowing streams occur, the aquatic larvae developing in such habitats. Dense larval populations are often found immediately below the outlets of lakes, ponds, or bogs (Fig. 586). Overwintering larvae complete their development in the spring, and adults emerge several days later. Outbreaks usually last a few days to a month or more but disappear in hot weather. After a blood meal the female flies deposit their eggs on objects near the surface of swiftly flowing water. Hatching occurs in approximately a week, the larvae feeding on aquatic microscopic plants and animals. The number of generations per year varies from one to several, depending on the species.

Treatment of the breeding areas has shown promise for killing adults and larvae. Airplane application has proved to be advantageous where large acreages are involved, and hand or ground equipment is feasible for small-scale operations easily accessible. The following chemicals have given good control: DDT, chlordane, heptachlor, aldrin, and dieldrin at dosages of 0.1 to 1.0 pound of actual insecticide per acre. The lower dosages are usually sufficient to kill the new larvae in streams, but a median dosage of those indicated is required to kill overwintering larvae, and the higher dosages are needed to kill adults and to give longer residual effect. The choice of chemical and dosage depends on possible effects on fish and other wildlife in the area to be treated. Field studies with DDT show that treating streams two or three times annually at a dosage of 0.1 pound per acre has controlled black fly larvae with very little effect on other stream arthropods. This treatment is widely employed for black fly control in resort areas of the Adirondack Mountains.

Plaster paris blocks impregnated with DDT and suspended by twine in the rapid portions of flowing streams release the chemical gradually to give satisfactory control of larvae. This treatment is supplemental to airplane larviciding. Details of making these blocks are given in the references at the end of this discussion. Adult control has been done primarily with mist blowers or fogging devices on an area-wide basis.

Repellents such as dimethyl carbate, diethyl toluamide, dimethyl phthalate, 2-ethyl-1,3-hexandiol (6–12), indalone, or the 6-2-2 mixture of the last three materials, have given two to seven hours' protection, depending on the species of black fly. When used alone 6–12 gave longer protection.

References: *J. Econ. Ent.*, 38:694–699, 1945; 43:696–697, 702–705, 1950; 44:813–814, 1951; 47:135–141, 1954; 54:607–608, 1961; 55:636–638, 1962.

BITING MIDGES, PUNKIES, AND SAND FLIES

Order Diptera

These are tiny blood-sucking flies that attack man and livestock in many parts of the country but are most abundant and annoying in the southern states and in the tropics. They are also vectors of disease organisms in various parts of the world. In some regions these flies have discouraged tourist trade and hindered real estate development.

Punkies are usually referred to as *Culicoides* species of the family Ceratopogonidae, and sand flies as *Phlebotomus* species of the family Psychodidae, but this is not true in all regions where these flies occur.

Culicoides furens (Poey) and *C. melleus* (Coquillett) are widely distributed species in tropical America from Brazil and the Mexican coast to the West Indies. Both occur along the coast of the United States from Massachusetts to Texas. In Florida they often appear in huge numbers

and are the most abundant and troublesome species. Many other species in this same genus are also found in this and other parts of the world. The heaviest breeding of *C. furens* is in dense mangrove salt marshes where the soil is well-shaded, contains much organic matter, and is continually wet. Marshes that are subject to daily floodings by high tides are particularly favorable for larval development. The flies deposit their eggs in the mud near the water. Hatching occurs in a few days, and the slender larvae burrow in the sand or swim about in the water, continue development for a period of six to eight months, then change to pupae. Adult emergence takes place about a week later. Sand fly development is quite similar.

Filling and impounding the water in breeding areas along coastlines has reduced populations of these flies. Treatment of intermittently flooded areas by using DDT, dieldrin, aldrin, or heptachlor at 1 pound per acre has given protection from this pest for the entire season. Lower dosages give shorter periods of protection. Aerial application, although more rapid, usually gives a shorter protection period than ground equipment with the same dosage of insecticide. Possible contamination of water sources and effects on wildlife should be considered before applying any chemical.

If control measures are directed only toward killing the adults, apply any of the aforementioned chemicals at a dosage of 0.1 to 0.5 pound per acre, formulated as solutions, emulsions, wettable powders, or dusts. Some control of larvae also results at this concentration.

Around the home control can be obtained by painting or spraying screens with solutions of 5% DDT, 2% chlordane or 6% deodorized malathion. Aerosols containing DDT and pyrethrins are of value in eliminating this pest in buildings. Repellents, as recommended for black flies (p. 646), also give some personal protection from these insects.

References: *J. Econ. Ent.*, 46:37–43, 1953; 55:521–527, 575–576, 1962; 56:719–720, 1963; *U.S. Pub. Health Monograph* 18, 1954.

EYE GNATS

Order Diptera, Family Chloropidae

These tiny flies in the genus *Hippelates* are annoying to man and other animals in areas having moist soils, especially those of sand or high in organic matter and under cultivation. The life cycle requires a period of three or four weeks, and breeding may continue throughout the year. They are attracted to the secretions of the mucous membranes of animals and are thought to be carriers of the organisms causing conjunctivitis in man. Although widely distributed, annoyance is probably greater in California and in the southern coastal states of the United States.

Treating soil where eye gnat larvae are developing with Telodrin, DDT, or endrin greatly reduced emergence of adults of *Hippelates collusor*

(Townsend). In experiments to kill adults of *H. pusio* Loew, lindane was best followed by dieldrin, and malathion. Further research is needed to solve this pest problem.

References: *J. Econ. Ent.*, 53:367–372, 1960; 54:130–131, 1961.

BLACK WIDOW SPIDER

Latrodectus mactans (F.), Family Theridiidae

Many species of spiders occur throughout the world, but possibly the most feared species is the black widow or hourglass spider (Fig. 587). They are more prevalent in the southern states, but they are also found

Fig. 587. The black widow spider, *Latrodectus mactans* (F.). (Knowlton, Utah Agr. Exp. Sta.)

in many areas farther north. Although their bites are likely to prove painful or even fatal, they are not often inflicted on man.

Another species said to be about as poisonous as the black widow spider is the brown recluse spider, *Loxosceles reclusa* Gertsch & Mulaik (Family Scytodidae). Both sexes bear the dorsal violin-shaped mark on the cephalothorax which makes recognition easy. This species is found in all states from Texas eastward into Georgia, and northward into Indiana, Illinois, Missouri, and Kansas.

Control of these species as well as other spiders can be accomplished by spraying outbuildings, under porches, around foundations, in basements, or other places likely to harbor spiders with either 2% chlordane or malathion, 0.5% dieldrin or dichlorvos, 1% ronnel or lindane, or 5% DDT. Dusts or sprays of these same chemicals applied to the lawn about the home will eliminate the spider problem.

References: *Calif. Agr. Exp. Sta. Bul.* 591, 1935; *Proc. North Central Branch, Ent. Soc. Amer.*, 19:115–118, 1964; *U.S.D.A. Agr. Handbook* 290, 1965.

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